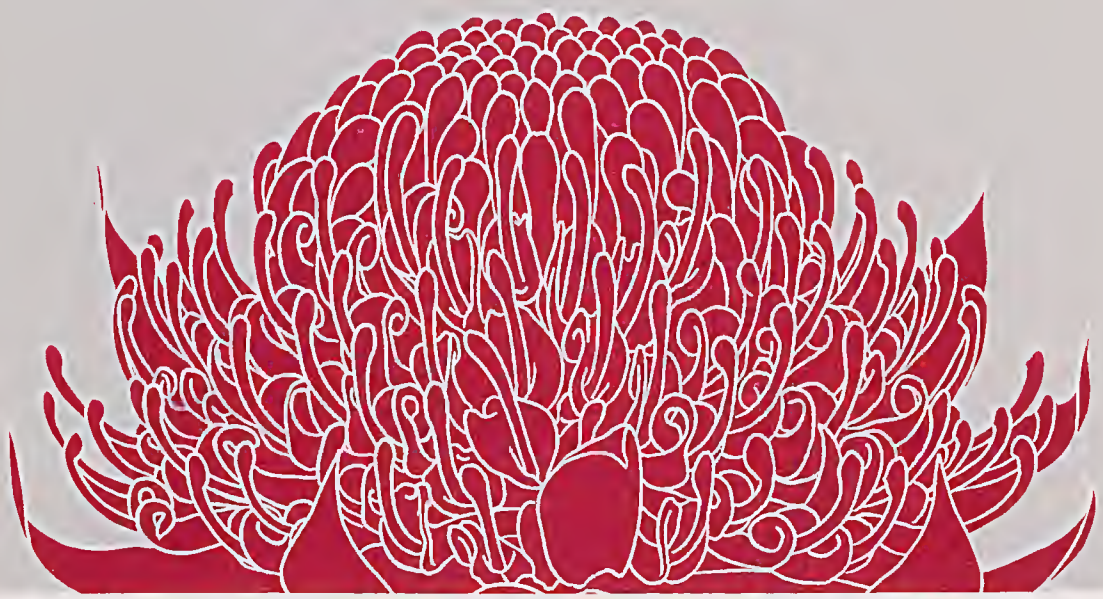
TELOPEA

Journal of Plant Systematics

Vol 11(4) • 2007



Botanic Gardens Trust
SYDNEY

National Herbarium of New South Wales

TELOPEA is published by the National Herbarium of New South Wales, Royal Botanic Gardens Sydney. It covers the field of systematic botany in Australia and the Asia-Pacific region, specialising in the flora of New South Wales.

TELOPEA is published twice yearly.

Annual subscription

*Within Australia**
Individuals $66*
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Website: http://plantnet.rbgsyd.nsw.gov.au/Telopea

Cover Artwork
Telopea speciosissima (Sm.) R. Br., adapted by Helen Stevenson from the original by David Mack

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ISSN 0312–9764
Telopea 11(3) was distributed on 13 November 2006.
National Herbarium of New South Wales
Royal Botanic Gardens Sydney
Mrs Macquaries Rd
Sydney NSW Australia 2000

Telopea 11(4) 393–397

Status of *Logania falcata* and *L.* sp. aff. *albiflora* (Loganiaceae)

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Abstract

Logania falcata Gand. is here lectotypified and reduced to the synonymy of *L. albiflora* R.Br. *Logania* sp. aff. *albiflora* (sensu Conn 1995a) is here regarded as a distinct species and formally named ***Logania granitica*** A.J.Whalen & B.J.Conn.

Introduction

The taxonomic revision of *Logania* section *Logania* (Conn 1995a) recognised several variants within *Logania albiflora*. However, none of these were formally circumscribed. This paper re-evaluates the status of *Logania* sp. aff. *albiflora* sensu B.J.Conn (Conn 1995a) based on extensive field studies and examination of ex situ plants cultivated at the Australian National Botanic Gardens, Canberra (Australian Capital Territory). It was necessary to re-evaluate the typification of *Logania falcata* Gand. because it appears, at least in part, to be conspecific with *L.* sp. aff. *albiflora* sensu B.J.Conn (1995a).

The herbarium collections examined during this study are cited according to the natural regions of Victoria (Conn 1993) and subdivisions of New South Wales (as cited in Harden 1990). The inflorescence terminology used in the description of *L. granitica* is based on Conn (1995b).

Taxonomy

1. *Logania falcata* Gand., *Bull. Soc. Bot. France* 70: 921 (1924).

Lectotype (**here chosen**): 'Buffalo Mts, Victoria', *Carl Walter s.n. ex herb Gandoger*, Oct 1902 (LY – three specimens on the right); *isolectotype:* NSW363313. Note: a photograph of the lectotype is available at PERTH1598929.

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Typification

The type material of *L. falcata*, as held at LY, consists of four flowering branchlets. The specimen on the left has small strongly recurved to revolute leaves, whereas the other three specimens have longer leaves which are also strongly recurved to revolute, but more falcate than the specimen on the left. Conn (1995a) reduced *Logania falcata* to the general synonymy of *L. albiflora* s. lat. specifying that this taxon was in part a synonym of the'Logania floribunda' variant and in part a synonym of the 'Logania falcata' variant. Conn (loc. cit.) did not lectotypify *L. falcata* but he did cite the type material under the 'Logania falcata' variant. Although the description of *L. falcata*, as provided in the protologue (Gandoger 1923), is very brief and slightly ambiguous, the reference to the spreading, elongated and flexuose branches ('Rami patuli elongate flexuosi') (ibid., p. 921) and falcate leaves ('folia ... falcata') more closely describes the three specimens on the right than it does the specimen on the left. Therefore, these three specimens are here selected as the lectotype of *L. falcata*. Since these three collections are referable to the 'Logania floribunda' variant (*sensu* Conn 1995a, pp. 594 & 595), *Logania falcata* is confirmed as a synonym of *L. albiflora* s. lat., as concluded by Conn.

2. ***Logania granitica*** A.J.Whalen & B.J.Conn, ***sp. nov.***

L. albiflorae affinis, a qua foliis sessilibus angustis, inflorescentiis paucifloris (floribus ad 9) differt.

Logania sp. aff. *albiflora* sensu B.J.Conn, *Austral. Syst. Bot.* 8: 597–599, fig. 1a (1995a) *pro parte* (see Notes below).

Logania falcata sensu B.J.Conn, *Austral. Syst. Bot.* 8: 594 & 595 (1995a), non Gandoger (1923) (excluding lectotype; see Notes below).

Holotype: Victoria: East Gippsland: summit of Mount Tingaringi [Tingaringy], on border of Victoria and New South Wales, c. 25 km W of Delegate, *A.E. Orchard* 2402, 30 Oct 1969 (MEL606972); isotypes: AD, BRI284792, NSW243557.

Illustration: Figure 1a (Conn 1995a).

Description

Spreading dioecious shrub to 1.5 m high; branches quadrangular, usually with two pairs of ridges laterally (forming 'angles'), midrib of lamina often extending down internode as a prominent ridge, minutely and densely hairy between the lateral ridges; hairs subpatent, c. 0.1 mm long. Leaves sessile; petiole not differentiated; stipules up to 1 mm long, soon reduced to a scarious scar; lamina subcoriaceous, linear, 7–30 mm long, 1–2.5 mm wide, juvenile leaves or leaves of young plants up to 6 mm wide [length to width ratio (5–)7–12]; base slightly narrowed, decurrent; margin entire, strongly recurved, such that lower surface hidden; lower surface densely, minutely papillose (margin and midrib glabrous, lacking papillae); upper surface glabrous. Inflorescence axillary, metabotryoidal or botryoidal (variously reduced), usually 3–9-flowered (♂), (1–)3-flowered (♀); flowers unisexual, not known if aromatic, with hypopodium (a_2 and a_3 axes) 0.3–0.7 mm long; anthopodium to 0.1 mm long; prophylls 0.5–0.8 mm long, with margin ± papillate to fimbriate; apex obtuse. Corolla white or cream-coloured, c. 2 mm long (for both ♂ and ♀); c. ⅔ connate; tube glabrous, sometimes internally with a thickened rim at mouth, c. 1 mm long; lobes with outer surface glabrous, inner surface minutely papillose (papillae

< 0.03 mm long). Stamens inserted c. ½ way up corolla tube; filaments 0.2–0.3 mm long, glabrous; anthers c. 0.3 mm long. Pistil 0.5–0.7 mm long (♂), 0.7–1 mm long (♀); ovary and style glabrous; stigma clavate (♂), ovoid-capitate, ± bilobed (♀). Capsule slightly flattened, ± ellipsoid to ± cylindrical, 3–5.5 mm long, 2–2.5 mm diameter, with style and stigma persisting for some time; seeds few per locule, fawn-coloured, slightly flattened-obloid, 1.8–2.2 mm long, c. 1 mm wide, minutely papillose.

Flowering: September to November. **Fruiting:** November to January.

Selected specimens (18 examined): **New South Wales:** Southern Tablelands: Namadgi National Park: 3 km NW of Booroomba Rocks, *Telford 10130*, 11 Dec 1985 (CBG8505037, MEL, NSW295665); Booroomba Rocks, *Gilmour 5774*, 1 May 1986 (CBG8605131, NSW 295668); Below bluff 500 m SW of Booroomba Rocks lookout, *Whalen 619*, 23 Nov 2000 (CANB621707, NSW); c. 12 km E of Corin Dam, *Adams 3907*, 13 Nov 1982 (CANB376724); 1 km S of Tooma Dam wall, *Duncan s.n.*, 8 Nov 1996 (NSW427446, MO, CANB516531); Kosciuszko National Park, W of Tooma Reservoir, *Gold s.n.*, 6 Dec 1994 (NSW414065). **Victoria:** East Gippsland: Mount Tingaringy summit, *Walsh 294*, 15 Sep 1979 (MEL595496). Snowfields: Mt Buffalo National Park, *Beauglehole 92177*, 17 Nov 1987 (MEL1594785). Mt Buffalo, Eagle Point area, *Willis s.n.*, 20 Feb 1963 (MEL2084404); The Watchtower (Neilson Crag), 7.7 km NE from Mt Arbuckle, *Walsh 1760*, 17 Oct 1987 (MEL1556355, NSW 244441, CBG 8905447).

Distribution: this species extends from Booroomba Rocks (A.C.T. — here included in the Southern Tablelands of N.S.W.) south through Kosciuszko National Park in New South Wales, to Mt Buffalo and Mt Tingaringy in Victoria. Although *Logania granitica* is distributed over a large area, it is only found on occasional sub-alpine mountain tops within this range. (Fig. 1).

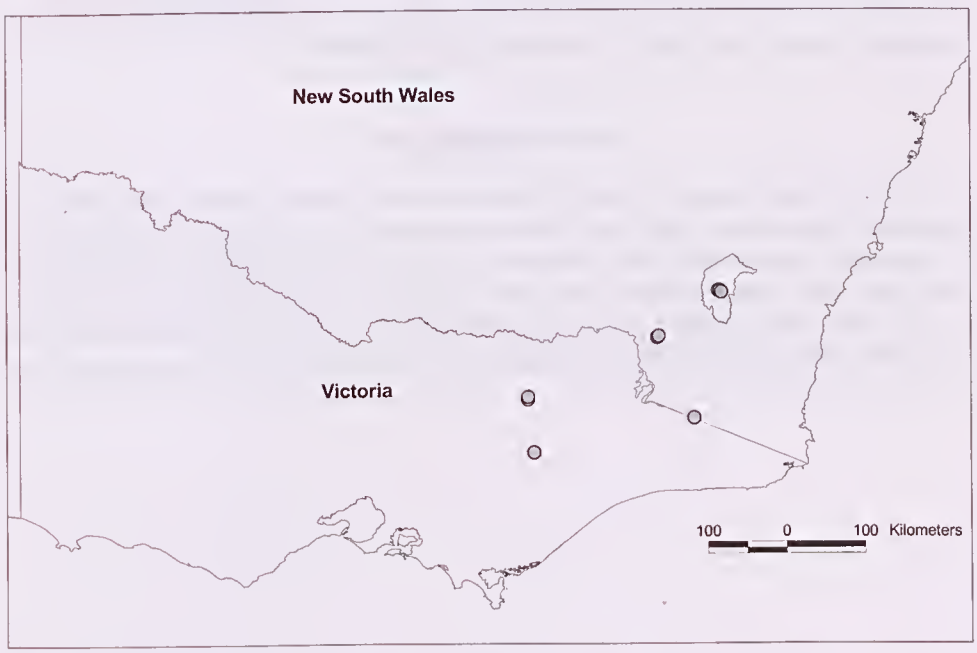

Fig. 1. Distribution map of *Logania granitica* in southern New South Wales and eastern Victoria.

Habitat: grows in heathland communities, in *Kunzea ericoides–K. muelleri* dominated shrublands or in subalpine eucalypt woodlands (dominated by *Eucalytus pauciflora*, *E. stellulata* or *E. niphophila*). It grows on rocky slopes or exposed hilltops in skeletal soils derived from a granitic substrate. This species occurs at high elevations (1200–1450 m).

Etymology: the specific epithet (namely 'granitica') refers to the habitat of large granite boulders amongst which this species dwells.

Notes: although the circumscription of *Logania granitica* is based on Conn (1995a, pp. 597–599, fig 1a), it has a narrower circumscription than that applied to *L.* sp. aff. *albiflora* sensu B.J.Conn (Conn 1995a). The latter taxon is largely included within *L. granitica*. However, one collection from 'Mongarlowe River' (*Cambage s.n.* Nov. 1908), identified by Conn (1995a) as *Logania* sp. aff. *albiflora*, is here considered to be part of a separate undescribed taxon (Whalen & Conn in prep.).

The affinities of *Logania granitica* are not known; however, it is here assumed to be most closely related to *L. albiflora* s. str.

With the lectotypification of *L. falcata* (refer above), the remaining specimen of this collection by *C. Walter s.n.* (LY) belongs to *L. granitica*. It is presumed that this specimen was gathered from the summit area of Mount Buffalo, whereas the other three specimens were from the slopes leading to the summit.

Conservation status: despite the limited number of known populations and the disjunction between each of these populations, this species is not considered to be at risk. It is thought that most populations are afforded adequate protection because they grow in rugged inaccessible sites within National Park reserves.

Logania granitica is a pioneer species, preferring open sites and responding vigorously to disturbance. In particular, seedlings of this species were found in abundance in the Namadgi National Park after the devastating 2003 bushfires.

Acknowledgments

We wish to thank Brendan Lepschi, Karina Richards, Marion Garratt, Dave Mallison and Julie Matarzyck (all CANB) for their companionship and assistance with fieldwork. We gratefully acknowledge the Directors and staff of the following herbaria who promptly made available their herbarium collections and/or facilities: BRI, CANB, HO, LY, MEL, NSW, PERTH. The ex situ collections were successfully cultivated at the Australian National Botanic Gardens, Canberra. We thank the staff of these gardens for their expert horticultural assistance.

References

Conn BJ (1992) *Logania*. Pp. 477–479 in Harden GJ (ed.) *Flora of New South Wales*, vol. 3. (New South Wales University Press: Kensington)

Conn BJ (1993) Natural regions and vegetation of Victoria. Pp. 79–158 in Foreman DB & Walsh NG (eds) *Flora of Victoria*, vol. 1. (Inkata Press: Melbourne)

Conn BJ (1995a) Taxonomic revision of *Logania* Section *Logania* (Loganiaceae). *Australian Systematic Botany* 8: 585–665.

Conn BJ (1995b) Description of inflorescence axes in the genus *Logania* R.Br. (Loganiaceae). *Kew Bulletin* 50: 777–783.

Gandoger M (1923) *Logania falcata* and *Logania orthophylla*. *Bulletin de la Société Botanique de France* 70: 921.

Harden, GJ (1990) Botanical divisions and subdivisions of New South Wales, pp. viii-ix. *Flora of New South Wales*, vol. 1 (New South Wales University Press: Kensington)

Manuscript received 04 August 2006, accepted 17 January 2007

Telopea 11(4) 399–403

Xanthostemon melanoxylon (Myrtaceae), a new species from the Solomon Islands

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Abstract

A new species from the Solomon Islands, ***Xanthostemon melanoxylon***, which is effectively restricted to lowland rainforest on ultramafic substrates, is described and its conservation status and relationships discussed.

Introduction

The genus *Xanthostemon* comprises approximately 47 species that are distributed from Australia and New Caledonia through to Sulawesi and the Philippines (Wilson 1996). The single Solomon Islands species was collected as early as 1958 but has remained unnamed despite first being mentioned in the literature following the Royal Society expedition to what was then known as the British Solomon Islands Protectorate in 1965 (Whitmore 1966, 1969). The heartwood of this tree, commonly known locally as *Tubi*, is extremely hard, durable and very dark, and has been compared with ebony. It is of great traditional importance, being used for walking sticks and, particularly, carved posts used to decorate buildings (Henderson & Hancock 1988). This endemic species has a limited distribution and is, therefore, rare. Increasing demand for the wood as a marketable resource has more recently raised conservation concerns due to the possibility of unsustainable harvesting. A conservation strategy for *Tubi* was finalised recently (Bulahite 2004) and the species has now acquired some level of legal protection. A formally published name is required for this species, and this is provided here.

Xanthostemon melanoxylon Peter G. Wilson & Pitisopa, ***sp. nov.***

a X. novoguineense colore ligni ebeneo, venis folii patentibus (vice rectangularibus) reticulo minus prominenti, floribus maioribus (petalis sepalisque maioribus, staminibus longioribus plus numerosis, stylo longiore) differt.

Type: Solomon Islands: Choiseul: Posarae [c. 7°21°S 157°14°E], *F. Pitisopa 13*, 17 March 2005 (holo NSW; iso CANB, BRI, USP, US, K, MO, NY, P, L).

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Tree to 35 m high and 80 cm dbh; outer bark shortly fibrous to scaly, brownish orange, outer blaze red-brown; inner blaze and sapwood mid-brown; heartwood dark brown to black. Young shoots and twigs sericeous, becoming puberulent. Leaves spirally arranged; petiole 5–10 (–19) mm long; lamina obovate to elliptical, (45–)50–90(–145) mm long, (18–)20–45 mm wide, (length:breadth ratio 1.65–2.8:1), subcoriaceous to coriaceous, secondary venation not particularly prominent, branching at 50–60° to the primary vein, apex obtuse to acute or acuminate, puberulent when young, ±glabrescent (hairs often persistent on petiole and midrib); oil glands numerous, conspicuous. Inflorescences crowded at apex of seasonal growth unit, subtended by somewhat reduced foliage leaves, axillary, axes densely white-puberulent; unit inflorescences triads or, rarely, metaxytriads (Briggs & Johnson 1979); peduncles 5–9 mm long; pedicels 3.5–6 mm long; bracteoles narrowly obovate, 3.3–4.2 mm long, 1.1–1.3 mm wide. Hypanthium cup-shaped, puberulent, 4.5–5 mm in diameter, c. 2–3 mm deep, just exceeding the summit of the ovary. Petals (4–)5, red, ovate to obovate, 6.5–7.1 mm long, 4.0–6.1 mm wide, margins ciliate with white hairs. Sepals (4–)5, deltoid to semicircular, somewhat unequal, 1.8–3.6 mm long, 2.0–3.5 mm wide, subglabrous on the outer surface. Stamens c. 30–32, mostly in a single series around the rim of the hypanthium, filaments 17–28 mm long, anthers 0.9–1.1 mm long, connective broad with a conspicuous large gland at the apex and probably other, smaller glands in the connective. Ovary 2.5–3 mm diameter, semi-superior, attached by its broad base, 3(–4)-locular, glabrous. Style 29–35 mm long, exceeding anthers by c. 5–10 mm; stigma narrower than the style. Placentas oblong to elliptical, projecting horizontally to the locular wall; ovules c. 22 per loculus, attached at the apex of the placenta and arranged in an uninterrupted whorl. Fruit broad-ovoid, 7–10 mm diameter, 5–7 mm high; hypanthium initially partly enclosing the base of the fruit; placentas bilaterally flattened, extending at most two-thirds of the way to the capsule wall. Seeds (not seen fully mature), ± deltoid, c. 3 mm long. (Fig. 1).

Selected specimens: Solomon Islands: Isabel Province: St George (San Jorge) Island, *Trenaman BSIP 307*, July 1958 (CANB, BRI n.v.). Choiseul Province: Boeboe, *Pitisopa 1–8*, 18 Nov 2004 (NSW); Posarae, *Pitisopa 9–12*, 18 Nov 2004 (NSW).

Derivation of name: the epithet is derived from the Greek *melas -anos*, black, and *xylon*, wood, in reference to the distinctive hard, dark heartwood.

Common names: *Tubi* (Isabel province – Bugotu, Maringe, Kia, Gao languages); *Rie* (Choiseul province – Avaso, Babatana languages). The common name 'Ebony' has also been used more recently for this species in trade in the Solomon Islands and some other countries due to the similarity of the wood to that of the true ebonies, *Diospyros* spp.

Distribution: this species has only been recorded from southern Isabel Province (San Jorge island and the southern part of Santa Isabel island) and Choiseul Province (south-eastern part of the island of Choiseul). A recent survey (Bulahite 2004) identified nine sites in Isabel Province and six in Choiseul.

Habitat: this species is mostly found in low diversity lowland forest on ultramafic-derived soils but has been recorded as occurring infrequently in rainforest on other soils. Ultramafic-derived soils are deep, freely draining yellowish-red or -brown clays and loams, typically with high mineral levels (chromium and nickel or magnesium). Ultramafic outcrops occur principally in the south of Santa Isabel (and adjacent San Jorge) and southern Choiseul, with a few scattered occurrences on Guadalcanal, the Florida Islands and San Cristobal. On these sites, the forest diversity is low and

Fig. 1. *Xanthostemon melanoxylon*. **a,** flowering shoot; **b,** capsules; **c,** leafy shoot; **d,** leaf; **e,** detail of leaf surface. (a from *Pitisopa 13* [8/18]; b, c from digital photos taken by Basil Gua; d, e from *Pitisopa 10*). Scale bar: a = 30 mm; b = 24 mm; c = 90 mm; d = 60 mm; e = 20 mm.

usually dominated by *Gymnostoma papuanum* and *Dillenia crenata*. In addition to the *Xanthostemon*, the only other species restricted to ultramafic sites (but not necessarily occurring at all sites) are *Hydriastele hombronii* (Arecaceae), *Myrtella beccarii* (Myrtaceae), and *Pandanus lamprocephalus* (Whitmore 1969, Hancock & Henderson 1988, Mueller-Dubois & Fosberg 1998).

Conservation status: the survey mentioned above (Bulahite 2004) indicates that there are reasonable stocking levels of *X. melanoxylon* at most locations visited but these populations are vulnerable to various threats, particularly logging, fire and mining. Over-harvesting is an unsustainable practice and can also lead to erosion and damage to the soil profile. Illegal logging of trees has been mitigated by a recent Forest Bill that has improved monitoring of such activities. Fire is also a possible threat since past burning of the vegetation on ultramafic sites has reportedly resulted in exposure of the soil surface over large areas and loss of upper soil horizons by sheet erosion (Lee 1969) that may lead to replacement of forest by open heath vegetation (Whitmore 1966). The recent survey (Bulahite 2004) found that most populations showed a good spread of age classes but fire damage at some sites had resulted in the death of all trees in affected parts of the populations. Some of these sites showed good regeneration from seed but these would be vulnerable to repeat burning. There are substantial nickel reserves on San Jorge Island, which is almost wholly composed of ultramafic rocks and their derived sediments, and prospecting licences have been issued. Exploitation of these mineral deposits could have a significant impact on the island's remaining *Tubi* populations.

Relatively recently, on 31 August 2005, regulations were gazetted that added *Tubi* to the list of protected species under the Forest Resources & Timber Utilisation Act (FR&TUA) (Protected Species) (Amendment) Regulations 2005 (Andrewartha pers. comm.).

Relationships: species of *Xanthostemon* fall into four groups based on placentation (Wilson 1990). Red flowered species (excluding the red-flowered segregate genus *Purpureostemon*) all have the horizontally projecting, rod-like placentas of the type species, *X. paradoxus*. Including this new species, there are only a relatively small number of red-flowered species in the genus and these can be divided into those that have a vesiculate hypanthium and those that do not. *Xanthostemon melanoxylon* lacks a vesiculate hypanthium and, on this criterion, is most closely related to *X. novoguineensis* from western New Guinea, a species that appears, from limited available site data, not to favour ultramafic sites. *Xanthostemon melanoxylon* can be distinguished from *X. novoguineensis* (based on published descriptions) by the heartwood colour, the angle of the secondary veins (50–60° compared with c. 90°), the less dense leaf reticulum, and the larger flowers (petals, sepals and style longer, stamens longer and more numerous). *Xanthostemon confertiflorus*, a red-flowered species from Sulawesi that does occur on ultramafic soils (Meijer 1983, van Balgooy & Tantra 1986, Proctor 2003), has a vesiculate hypanthium and is, therefore, more closely related to *X. speciosus*, that is also found on ultramafic substrates from the Philippines (Palawan and Culion/Busuanga).

Acknowledgments

PGW is grateful to Bronwyn Clarke (SPRIG Project, ENSIS) for her assistance in bringing specimens of this species to Sydney for detailed study and illustration. Thanks also to Adam Williams and Lex Thomson (SPRIG Project, ENSIS), and Ross Andrewartha

(AusAID Forest Management Project) for background information relating to *Tubi* and its conservation status. We thank Catherine Wardrop for her detailed illustration.

References

Balgooy MMJ van & Tantra IGM (1986) The vegetation in two areas in Sulawesi, Indonesia. *Forest Research Bulletin* (special edition), Indonesia: Bogor.

Briggs BG & Johnson LAS (1979) Evolution in the Myrtaceae evidence from inflorescence structure. *Proceedings of the Linnean Society of New South Wales* 102: 158–256.

Bulahite K (2004) Conservation and sustainable management strategy for *Xanthostemon* sp. Unpublished report produced for Department of Forestry, Environment and Conservation, Solomon Islands.

Hancock IR & Henderson CP (1988) Flora of the Solomon Islands. Research Bulletin no.7. Ministry of Agriculture and Lands, Solomon Islands: Honiara.

Henderson CP & Hancock IR (1988) A guide to the useful plants of Solomon Islands. Ministry of Agriculture and Lands, Solomon Islands: Honiara.

Lee KE (1969) Some soils of the British Solomon Islands Protectorate. *Philosophical Transactions of the Royal Society*, B 225: 211–258.

Meijer W (1983) Botanical explorations in Celebes and Bali. National Geographic Society Research Report 1976 Projects, pp. 583–605.

Mueller-Dombois D, Fosberg FR (1998) Vegetation of the tropical Pacific Islands. Springer-Verlag: New York.

Proctor J (2003) Vegetation and soil and plant chemistry on ultramafic rocks in the tropical Far East. *Perspectives in Plant Ecology, Evolution and Systematics* 6 (1–2): 105–124.

Whitmore TC (1966) *Guide to the forests of the British Solomon Islands.* (Oxford University Press: Oxford)

Whitmore TC (1969) The vegetation of the Solomon Islands. *Philosophical Transactions of the Royal Society*, B 225: 259–270.

Wilson PG (1990) A revision of the genus *Xanthostemon* (Myrtaceae) in Australia. *Telopea* 3: 451–476.

Wilson PG (1996) Myrtaceae in the Pacific, with special reference to *Metrosideros*. Pp. 233–245 in Keast A & Miller SE (eds), *The origin and evolution of Pacific Island biotas, New Guinea to Eastern Polynesia: patterns and processes*. (SPB Academic Publishing: Amsterdam)

Manuscript received 14 August 2006, accepted 05 February 2007

Telopea 11(4) 405–411

A new species of *Nematoceras* and characterisation of *N. dienemum* (Orchidaceae), both from subantarctic Macquarie Island

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Abstract

Two species of *Nematoceras* (Orchidaceae) from subantarctic Macquarie Island are characterised, illustrated and details of distribution and ecology are provided. ***Nematoceras sulcatum*** M.A.Clem. et D.L.Jones, recently identified by field studies and confirmed by comparative morphological and DNA analyses, is described as new.

Introduction

Macquarie Island is an isolated subantarctic island in the Southern Ocean located at 54°30'S, 158°56'E, c.1500 km SSE of Tasmania, approximately halfway to the Antarctic continent. The island is approximately 34 km long and up to 5.5 km wide with an undulating north-south trending plateau 200–350m above sea level. It was formed by tectonic uplift of the ocean floor 600,000–700,000 y.b.p. and has never been connected to any other land mass (Adamson et al. 1996). The flora of Macquarie Island, which has been the subject of much research, shows affinities with that of other southern ocean islands, and has established after long-distance transoceanic dispersal of seeds and spores (Bergstrom & Selkirk 1987). The flora is restricted to bryophytes, lichens and low-growing vascular plants, and distinct vegetation communities are found on the coastal terraces, coastal slopes and plateau uplands (Selkirk et al. 1990).

The first record of Orchidaceae from Macquarie Island was a species of *Corybas* (Acianthinae: Diurideae) discovered on the raised beach terraces of the north-west coast (Brown et al. 1978) and identified by the New Zealand botanist, Elizabeth Edgar, as *Corybas macranthus*. It was subsequently shown to be morphologically distinct from *C. macranthus* and was described as *C. dienemus* D.L.Jones (Jones 1993). Soon after in a detailed study of Diurideae but in particular Acianthinae, based on analysis of morphological and sequence data, using the internal transcribed spacer (ITS) region of the 18–26S nuclear ribosomal DNA, (Clements et al. 2002), the genus *Nematoceras* was re-instated as distinct from *Corybas*. Jones et al. (2002) subsequently transferred

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C. dienemus to the genus *Nematoceras*, *viz. N. dienemum* (D.L.Jones) D.L.Jones, M.A.Clem. et Molloy (as "*dienema*"). *Nematoceras* is recognised as distinct from *Corybas* by possession of: flowers with relatively narrow dorsal sepal; lateral sepals and petals subsimilar, long, narrow and erect; labellum large, tubular or flared, auricles open-ended; callus of a thickened medial ridge; and column short, squat and lacking a swollen ventral pad (Jones et al. 2002).

During recent field work on Macquarie Island, leaf material of a possible second species of *Nematoceras* was collected on the upland plateau terraces of the Sawyer Creek valley. A study of the herbarium collections held at the Tasmanian Herbarium (HO) and an analysis of the Internal Transcribed Spacer (ITS) DNA region, where there was a difference of 17 bases (2.5%), suggested the existence of a second species on the island (Mackenzie et al. 2005) details of which will be published in a companion paper (Clements et al. 2007, in press). Flowering material located during later field work confirmed the distinctiveness of this second *Nematoceras*. The new species is described and illustrated here with supplementary ecological data and the opportunity is also taken to fully characterise and illustrate *N. dienemum*, the species originally described from Macquarie Island.

Taxonomy

Nematoceras sulcatum M.A.Clem. & D.L.Jones, ***sp. nov.***

Affinis *Nematoceras trilobo* Hook.f., sed flore exorienti infra petiolo fere medio, erecto; petalis et sepalis lateralibus filiformibus, erectis, sepalis longitudinibus fere duplo petalis; sepalo dorsali anguste spathulato obtuso cucullato, atropurpureo; labello minor, umbone centrali sulcato citreo; marginibus labelli leviter incurvatis, atroviolaceis, ad apicem minute erosis, differt.

Holotype: Macquarie Island, 54°30'S, 158°56'E, *G. Copson & G. Leaman s.n.*, 23 Nov 1980 (HO 91827).

Terrestrial tuberous *herb*, glabrous, deciduous, forming clonal colonies. *Tubers* globose to ellipsoid, 1–7 mm long, 1–6 mm wide. *Stolonoid roots* 40–90 mm long, c. 1 mm thick. *Leaf* solitary, held at the substrate surface, flat to shallowly concave, petiolate; lamina orbicular, 12–20 mm long, 12–20 mm wide, light green with visible veins above, silvery green beneath; apiculate. *Petiole* arising below substrate surface, fleshy, 12–16 mm long, 1.5–2 mm thick, slightly recurved. *Pedicel* green, 5–7 mm long, 1–1.5 mm thick, fleshy. Floral bract erect, membranous, not sheathing, lanceolate when flattened, 5–8 mm long, 1.5–2 mm wide. *Ovary* erect, asymmetric, fleshy, 5–8 long, 1–1.5 mm wide. *Inflorescence*, arising c. halfway along the petiole below the leaf lamina. *Flower* erect, with most parts dark red, 25–30 long, 10–14 mm wide. *Dorsal sepal* spathulate when flattened, 14–17 mm long, 5–6.5 mm wide, incurved, cucullate over most of the labellum, dark red, lighter and striate towards the base, apex apiculate. *Lateral sepals* exceeding the dorsal sepal, erect to spreading, filiform, 27–30 mm long, c. 0.8 mm wide at the base, dark red, lighter towards the base. *Petals* erect to spreading, filiform, 11–13 mm long, c. 0.6 mm wide, dark red, lighter towards the base. *Labellum* mostly hidden by the dorsal sepal, dark red; labellum tube 5–7 mm long then abruptly deflexed through 180° and expanded into the lamina; lamina broadly ovate to orbicular, 12–15 mm long, 8–10 mm wide, the margins incurved, irregular to denticulate; boss prominent, cream to pale yellow, with a deep central groove. *Column* erect, 2.5–3 mm long, c. 0.7 mm

wide, obscurely winged. *Anther* porrect, c. 1.2 mm long, erostrate. *Pollinia* cream to white, sessile on an ovate viscidium. Stigma circular, c. 0.8 mm wide, concave, margins entire. *Capsule* not seen. (Fig. 1).

Etymology: from the Latin *sulcatus* grooved, furrowed, channelled, in reference to the prominent groove in the labellum boss.

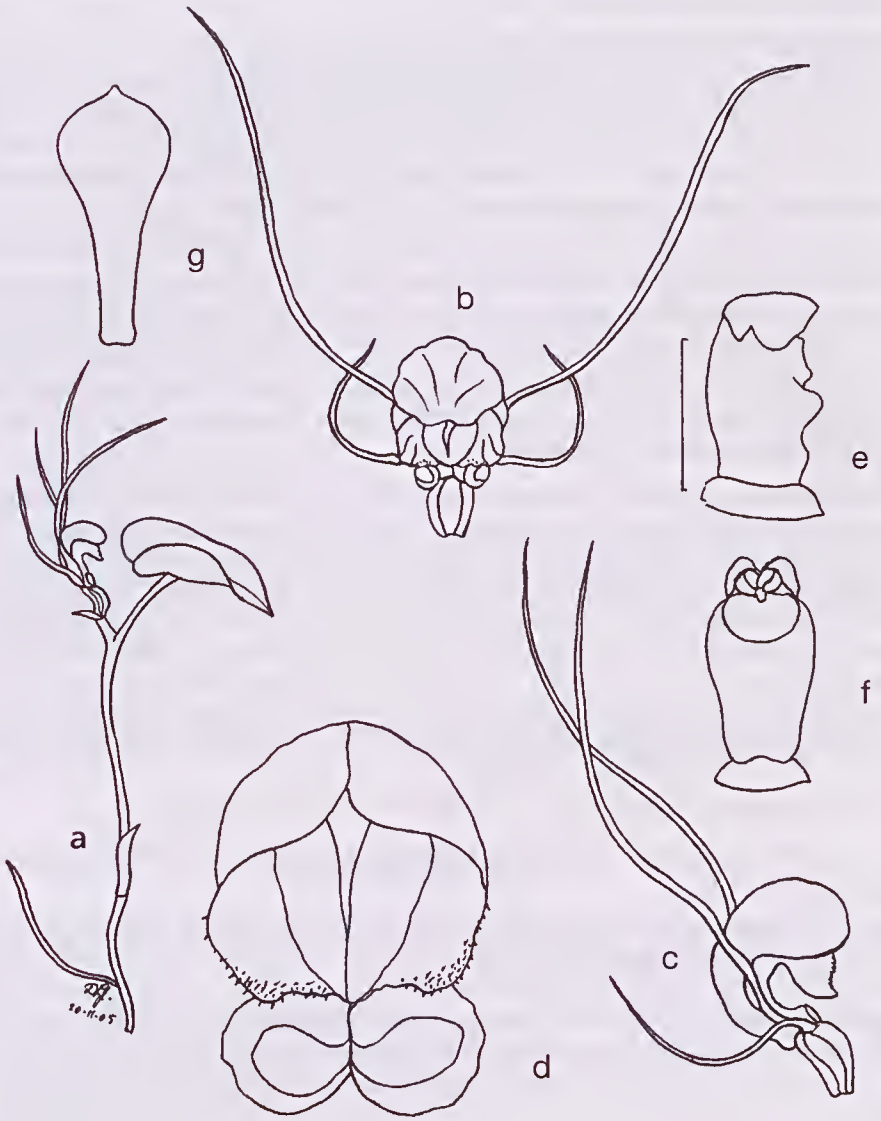

Fig. 1. *Nematoceras sulcatum*. **a**, flowering plant from side; **b**, flower from front; **c**, flower from side; **d**, flower from front, lateral sepals and petals removed; **e**, column from side; **f**, column from front; **g**, dorsal sepal flattened (all from *Carmichael ORG 5135*). Scale bar: a = 20 mm; b, c, g = 10 mm; d = 8 mm; e, f = 2 mm. Illustration by D.L. Jones.

Distribution and ecology: endemic to Macquarie Island where it occurs on part of the plateau uplands, growing in wet grassy seepage areas along the eastern side of the Sawyer Creek Valley at 80–150m alt. One site is c. 1.2 km south of the Green Gorge Mire alongside the old Overland walking track; another site occurs to the west of the Overland walking track 0.75 kilometres north of Pyramid Lake. The vegetation is mainly short grassland dominated by *Festuca contracta*, *Agrostis magellanica* and *Luzula crinita*, with mosses and liverworts. The water table is close to the surface but there is some drainage due to the slopes of the terraces alongside Sawyer Creek. Flowering period: November–December.

Recognition: *Nematoceras sulcatum* is readily distinguished from *N. dienemum* by its dark red flowers, obovate-spathulate dorsal sepal that is strongly incurved and cucullate over the labellum and a broadly ovate to orbicular labellum lamina with a prominent cream to pale yellow deeply grooved boss. The new species is probably most closely allied to the New Zealand species *N. trilobum* Hook.f., from which it can be distinguished by the dark red flower arising from below the leaf lamina, narrowly obovate-spathulate dorsal sepal, and smaller ovate-orbicular labellum with a denticulate apical margin.

Notes: *Nematoceras sulcatum* is the second orchid species described from Macquarie Island and field studies suggest that each species may occupy a different habitat (see notes under *Nematoceras dienemum*). It is also worth noting that, although the viscidium was reported as lost in the common ancestor of "Corysanthinae" (which includes *Corybas* and *Nematoceras*) plus *Cyrtostylis* (Clements et al. 2002), correctly this loss only occurred in *Cyrtostylis*.

Other specimens examined: Macquarie Island: without specific locality, 22 Nov 1980, *Copson & Leaman s.n.* (HO 91825); Green Gorge, 6 Nov 1980, *G. Copson s.n.* (HO 91831); Sawyer Creek, 54°38'25.0"S, 158°53'00.7"E, 16 Feb 2004, *Skotnicki, Mackenzie & Selkirk K632* (CANB, sterile); Sawyer Creek, 54°38'24.5"S, 158°53'03.7"E, 16 Feb 2004, *Skotnicki, Mackenzie & Selkirk K633* (CANB sterile); North of Pyramid Peak, 54°39'08.9"S, 158°52'46.8"E, 3 Mar 2004, *Skotnicki, Mackenzie & Selkirk K1358* (CANB sterile); site K632, Pyramid Peak, Jan 2005, *Carmichael (ORG 5135)* (CANB).

Nematoceras dienemum (D.L.Jones) D.L.Jones, M.A.Clem. et Molloy, *Orchadian* 13(10): 449 (30 Jan. 2002) (as '*dienema*')

Corybas dienemus D.L.Jones, *Fl. Australia* 50: 572, f. 90 F–G (1993).

Corybas macranthus auct. non (Hook.f.) Rchb.f.: M.J.Brown et al., New Zealand J. Bot. 16: 405–407 (1978).

Holotype: 'N of Bauer Bay, Macquarie Is.', *J.R. Croft 10445*, 27 Nov.1989 (CANB!); isotypes (HO!, MEL!, NSW!, WELT!).

Terrestrial tuberous *herb*, glabrous, deciduous, forming small clonal groups. *Tubers* globose to ellipsoid, 1–5 mm long, 1–5 mm wide. *Stolonoid roots* 5–35 mm long, c. 1 mm thick. *Leaf* solitary, held at the substrate surface, cupulate, petiolate; lamina orbicular, 12–20 mm long, 14–23 mm wide, dark green above, silvery green beneath, thick, fleshy; base cordate; apex apiculate. *Petiole* arising below substrate surface, fleshy, 10–20 mm long, 1.5–2 mm thick. *Pedicel* vestigial, green, c. 1 mm long, 1–1.3 mm thick. Floral bract erect, membranous, sheathing, ovate-deltate when flattened, 5–6 mm long, 3–3.5 mm wide. *Ovary* erect, asymmetric, fleshy, 3–6 mm long, 2–2.5 mm wide. *Inflorescence* arising on the petiole. *Flower* erect, nestling in the leaf base, green with

purplish-red markings, 25–30 mm long, 20–25 mm wide. *Dorsal sepal* incurved with a recurved apex, partially cucullate over the labellum, oblong when flattened, 12–15 mm long, 2.5–3 mm wide, with irregular dark striae; apex acute to acuminate with involute margins. *Lateral sepals* exceeding the dorsal sepal, erect, filiform, 30–33 mm long, c. 1.5 mm wide at the base, lightly twisted, with scattered dark marks. *Petals* erect to recurved, filiform, 23–25 mm long, c. 1.5 mm wide, with scattered dark marks. *Labellum* apex protruding, purplish red; labellum tube 3–5 mm long then abruptly recurved at 90° and expanded into the lamina; lamina ovate, 6.5–7.5 mm long, 12–15 mm wide, the margins incurved, irregular to denticulate; boss not prominent, purplish red; apex shortly caudate. *Column* procumbent, 3–3.5 mm long, c. 2 mm wide, obscurely winged. *Anther* porrect, c. 1.3 mm long, erostrate, shortly dentiform. *Pollinia* cream to white, sessile on an elliptic viscidium. Stigma elliptical, c. 1.2 mm wide, concave, with strongly dentiform margins. *Capsules* ovoid, 9–11 mm long, 3–4 mm wide, held erect on a thickened peduncle 4–8 cm long. (Fig. 2).

Distribution and ecology: *Nematoceras dienemum* inhabits the lower coastal terraces (<20m above sea level) and the Green Gorge mire where the vegetation is dominated by bryophytes (mosses) which "float" on a waterlogged underlayer (featherbed). Flowering period: November– January. By contrast *N. sulcatum* has only been found in short grassland communities on the plateau uplands at 80–150m above sea level.

Recognition: *Nematoceras dienemum* is readily distinguished from *N. sulcatum* by its green flowers with purplish-red markings, oblong dorsal sepal that is shallowly incurved with a recurved acute to acuminate apex with involute margins and an ovate labellum with an inconspicuous purplish-red boss.

Notes: the affinities of *N. dienemum* are unclear but probably lie with *Nematoceras* species from the South Island of New Zealand. The friable nature of the pollen suggests autogamy in this species. The dentiform margins of the stigma are an unusual and noteworthy feature.

Other specimens examined: Macquarie Island: without specific locality, 12 Nov 1980, *Copson s.n.* (HO 91824); Half Moon Bay, 12 Nov 1980, *Copson s.n.* (HO 91823); without specific locality, 24 Nov 1980, *Copson & Leaman s.n.* (HO 91826); Green Gorge, 24 Feb 1980, *Leaman & Copson s.n.* (HO 91829).

Acknowledgments

We thank the Curator of Tasmanian Herbarium (HO) for loan of the specimens. Mary Skotnicki, Patricia Selkirk, Anne Mackenzie, Noel Carmichael and Jenny Sheridan provided samples collected in 2004 with permission from Tasmanian Parks and Wildlife Service and from Tasmanian Resource Management and Conservation. Logistical support for fieldwork was provided by the Australian Antarctic Division. Geoff Copson kindly provided details of orchid localities on Macquarie Island for collection of the above samples.

References

Adamson DA, Selkirk PM, Price DM, Ward N & Selkirk JM (1996) Pleistocene uplift and palaeoenvironments of Macquarie Island: evidence from palaeobeaches and sedimentary deposits. *Papers and Proceedings of the Royal Society of Tasmania* 130: 25–32.

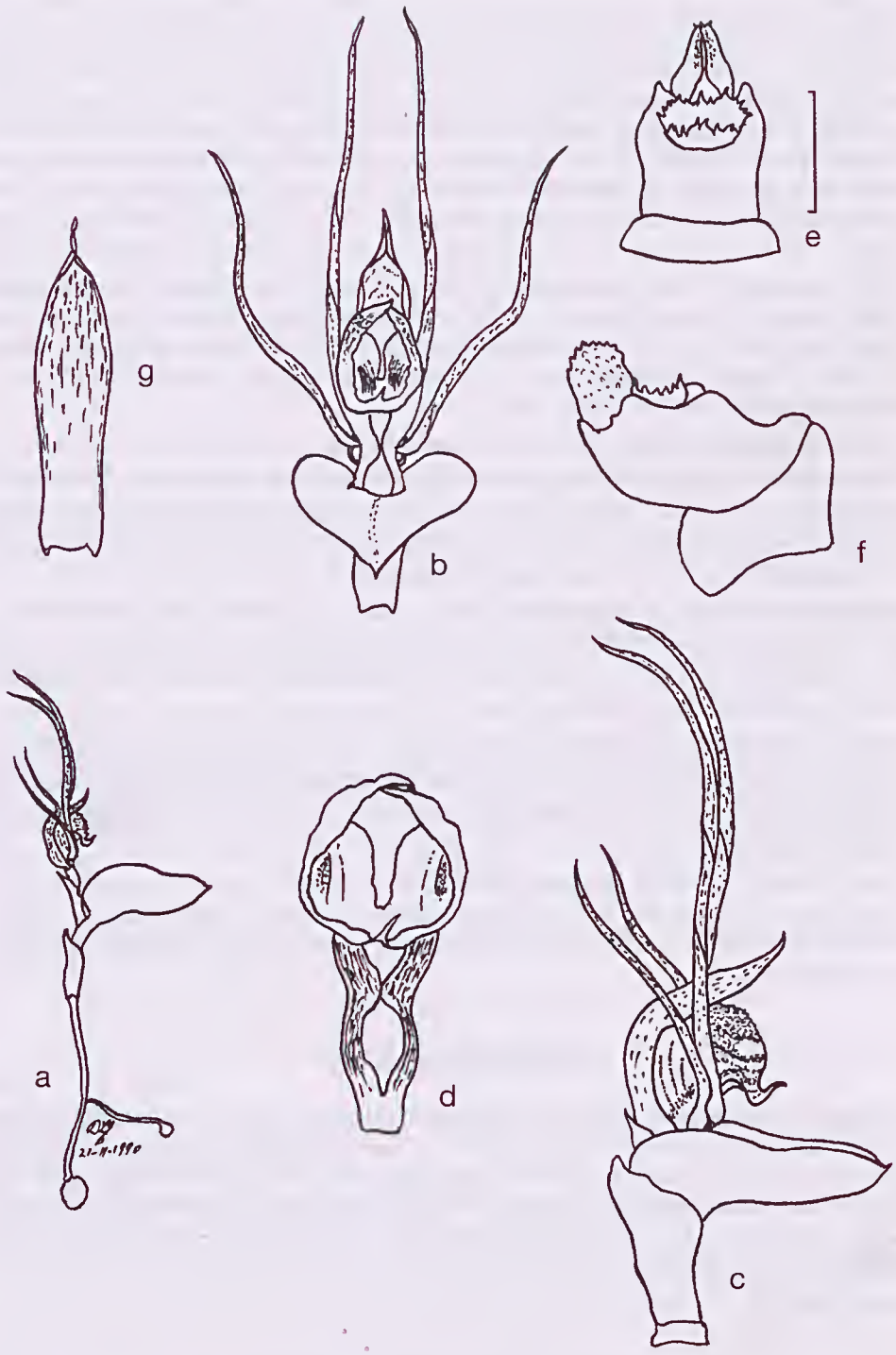

Fig. 2. *Nematoceras dienemum*. **a**, flowering plant from side; **b**, leaf and flower from front; **c**, leaf and flower from side; **d**, labellum from front; e. column from side; **f**, column from front; **g**, dorsal sepal flattened (all from *cult. ex Croft 10445*). Scale bar: a = 20 mm; b, c = 10 mm; d, g = 5 mm; e, f = 2 mm. Illustration by D.L. Jones.

Bergstrom DM & Selkirk PM (1987) Reproduction and dispersal of mosses on Macquarie Island. *Symposia Biologica Hungarica* 35: 247–257.

Brown MJ, Jenkin JF, Brothers NP & Copson GR (1978) *Corybas macranthus* (Hook.f.) Reichb. f. (Orchidaceae), a new record for Macquarie Island. *New Zealand Journal of Botany* 16: 405–407.

Clements MA, Jones DL, Sharma IK, Nightingale ME, Garratt MJ, Fitzgerald KJ, Mackenzie AM & Molloy BPJ (2002) Phylogenetic systematics of the Diurideae (Orchidaceae) based on the ITS and 5.8S coding region of nuclear ribosomal DNA. *Lindleyana* 17: 135–171.

Clements MA, Mackenzie AM, Copson GR, Molloy BPJ, Carmichael N, Skotnicki, ML & Selkirk PM (2007, in press) Biology and molecular phylogenetics of *Nematoceras sulcatum*, a second endemic orchid species from subantarctic Macquarie Island. *Polar Biology*.

Jones DL (1993) Orchidaceae (Macquarie Island). P. 572 in Hewson HJ & Thompson HS (eds) *Flora of Australia*, vol. 50, Oceanic Islands, vol. 2. (Australian Government Publishing Service: Canberra)

Jones DL, Clements MA, Sharma IK, Mackenzie AM & Molloy BPJ (2002) Nomenclatural notes arising from studies into the tribe Diurideae (Orchidaceae). *Orchadian* 13(10): 437–468.

Mackenzie AM, Carmichael N, Clements MA, Copson GR, Selkirk PM & Skotnicki ML (2005a) Australia's Subantarctic Orchids. Pp 321–324 in Raynal-Roques A, Roguenant A & Prat D (eds) *Proceedings of the 18th World Orchid Conference March 11–20, 2005, Dijon-France.* (Naturalia: France)

Selkirk PM, Seppelt RD & Selkirk DR (1990) *Subantarctic Macquarie Island: environment and biology.* (Cambridge University Press: Cambridge)

Manuscript received 16 June 2006, accepted 22 February 2007

Telopea 11(4) 413–417

Trochocarpa montana (Ericaceae), an endemic new species from the Northern Tablelands area of north-eastern New South Wales

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Abstract

Trochocarpa montana J.B.Williams & J.T.Hunter, a restricted montane species from the Northern Tablelands area of New South Wales is described. Notes are provided on its distribution, ecology and conservation status.

Introduction

A mountain form of *Trochocarpa laurina* has been recognised, described informally and treated as a separate taxon in works such as Williams et al. (1984), Floyd (1989), Wiecek (1989) and more recently Harden et al. (2006). This putative taxon has also been included in molecular phylogenetic analyses of the tribe Styphelieae (Quinn et al. 2003). The senior author was preparing descriptions of a number of new taxa over recent years, but his untimely death prevented their completion. Publications of some of these have recently appeared (Hunter et al. 2006; Williams & Hunter 2006) but others still await formal description. This paper presents the formal description of the distinct mountain form of *Trochocarpa laurina* from the Northern Tablelands region of New South Wales as a separate species.

Trochocarpa montana J.B.Williams & J.T.Hunter, ***sp. nov.***

T. laurinae similis sed foliis minoribus fimbriatis alternatis (haud pseudoverticillatis), fructu minore, caulibus, bracteis bracteolisque hirsutis differt.

Trochocarpa species, *sensu* Floyd (1989, p. 123); Harden et al. (2006, p. 142).

Trochocarpa sp. A., *sensu* Wiecek (1992, p. 434).

Illustrations: Floyd (1989, p. 123); Wiecek (1992, p. 434); Harden et al. (2006, p. 142).

Type: New South Wales: Northern Tablelands: c. 2 km NW of Round Mountain, Cathedral Rock NP (30°24'46"S 151°13'02"E), *J.T. Hunter 2579, J.J. Bruhl & F.C. Quinn*, 21 Jan 1995 (holo: NSW; iso: BRI, HO, MEL, NE).

† Deceased 31 July 2005

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Much-branched *shrub* to 2–10 m tall; branchlets fawn to grey, shortly pubescent to scabrous or very rarely glabrescent with age. *Leaves* alternate, spread along stems; narrowly ovate, narrow-elliptic to broadly ovate, slightly asymmetric; 1.05–5 cm long, 0.4–2.6 cm wide; veins 7, at least 5 usually easily visible though sometimes obscure especially adaxially; margins distinctly thickened, slightly recurved; base broadly tapering; acute; tip usually obtuse (due to apex dying), sometimes abruptly so, or rarely acute, always dry, brown and brittle; usually glabrous except for scabrous hairs restricted to the edges or more rarely minutely scabrous to sparsely pustulate adaxially; margins minutely fimbriate to minutely ciliate, usually restricted or more prominent in the distal third but sometimes along the whole margin; glossy deep green above, paler abaxially, new growth red. Petiole 1.5–4.5 mm long; shortly pubescent, rarely hairs restricted to adaxial groove. Caducous early season growth bracts to 4.2 mm long, marginally ciliate, pubescent abaxially on distal half. *Inflorescences* terminal and axillary racemes of c. 20 flowers. Pedicels 0.2–0.5 mm long. Bracts 1.1–1.6 mm long, 1–1.1 mm wide, sometimes keeled, margins ciliate, pubescent abaxially on distal half. Bracteoles 1–1.1 mm long, ovate to elliptic, margins ciliate, sometimes keeled and pubescent abaxially on the distal half. Calyx 1.2-2 mm long, 0.6–1.1 mm wide; ovate to elliptic; margins ciliate, pubescent abaxially on the distal half. Petals 2.8–3.5 mm long; tube broader above, 1.6–2.1 mm long, 1.4–2.1 mm wide at the mouth; lobes erect to spreading, 1.2–1.6 mm long, 1–1.3 mm wide; lobes and top half of the tube adaxially densely hairy, hairs spreading on lobes and reflexed in tube, hairs 0.3–1 mm long, margins papillate. *Anthers* dorsally apically connected to the filaments, 0.7–1.1 mm long; filaments 0.6–0.8 mm long. *Ovary* 0.7–0.9 mm long; 0.7–0.9 mm wide; disc prominently toothed to undulate, 0.4–0.6 mm high. Style 0.4–0.7 mm long, with a broad base. *Fruit* 4.5–6 mm wide, 7–11 locular, purple to black, depressed globose; seed 2.5–3.5 mm long, 1.5–2.5 mm wide. Flowering mainly late September to October.

Additional specimens examined: New South Wales: Northern Tablelands: Point Lookout, *McCusker*, 17 Dec 1956; Point Lookout, *Tayles*, 16 Mar 1958; Point Lookout, NENP, *Hore-Lacy*, 12 Feb 1963; Point Lookout, *Wissmann*, Oct 1989; Track to Wrights Lookout, New England National Park, *Telford 12669 & Bruhl*, 11 Dec 2003; 14 km east of Ebor, 7 km along Dawsons Rd, *Needham*, 14 Mar 1999; Tom's Cabin, New England NP, *Williams*, Jun 1976; Tom's Cabin, Point Lookout, *Sawyer*, 28 Sep 1989; Softwood Rd, Styx River Forest Way, Styx River SF, *Williams*, 22 Apr 1978; Snowy Creek, Ebor, *Wissmann*, 26 Oct 1969; Slopes SE of Cathedral Rock, near Ebor, *Smith 20*, 25 Sep 1974; Cathedral Rock NP, near Ebor, SE of Cathedral Rock, *Smith 187*, 21 Mar 1975; Mt Hyland NR, *Williams*, 30 Oct 1985; Cobark, Gloucester to Barrington Tops Road, *Griffith*, 15 Jul 1982; Barrington Tops, west of Gloucester, *Williams*, 12 Jul 1983; Plateau Beech Reserve, Werrikimbe NP (N of Yarras), *Bale*, May 1989; Werrikimbe, upper Forbes River, *Bale*, Jun 1989; Site 14, Ngulin NR flora survey, *Hunter*, 9 Sep 2005; Site 16, Ngulin NR flora survey, *Hunter*, 9 Sep 2005. (All NE).

Distribution: the known populations are all restricted to altitudes above 1000 m in seven general locations; the Styx River area, New England and Cathedral Rock National Parks and Mt Hyland Nature Reserve around Ebor and Werrikimbe National Park (Walcha), Nbulan Nature Reserve (Nowendoc) and the Barrington Tops area (Fig. 1).

Habitat: commonly found in and on the margins of *Nothofagus moorei* cool temperate rainforest and warm temperate rainforest but also in tall wet eucalypt forests dominated by *Eucalytpus obliqua* (Floyd 1989; Clarke et al. 2000; Hunter 2005; Harden et al. 2006); at altitudes between 1000 and 1600 m. The species has been found on a variety of rock types from basalt, acid volcanics, phyllites and granite with soils that are usually clay loams.

Notes: this species is closest to *Trochocarpa laurina* (Rudge) R.Br. in overall features but differs in the combination of a number of characters (Table 1). Most notable is the smaller size of many features, particularly the leaves and fruits. In addition *T. montana* is hairy on the branchlets, petioles, leaf margins (sometimes adaxial leaf surface) and on the abaxial surface of bracts, bracteoles and sepals, whereas *T. laurina* is glabrous on these parts. The phyllotaxy is also different, being distinctly alternate in *T. montana* and pseudo-whorled in *T. laurina*; overall leaf shape is different, with *T. montana* being usually broadest below the middle, (similar to *T. bellendenkerrensis* Domin), whereas *T. laurina* is broadest at the middle. Small-leaved forms of *T. laurina* have been found near Dorrigo and Tenterfield in New South Wales and the Lamington area of south-east Queensland which superficially resemble *T. montana* solely due to foliage size. These small-leaved *T. laurina* do not possess any of the other diagnostic features of *T. montana* (Table 1). Specimens of *T. montana* from the Walcha, Nowendoc and Barrington Tops areas differ from the type form in having larger and broader leaves and a generally more dense and longer indumentum on most parts.

Table 1. Diagnostic characters separating *Trochocarpa montana* from *T. laurina*.

Feature	*T. montana*	*T. laurina*
Stems	densely to sparsely shortly pubescent, rounded to angular, grey to fawn	glabrous angular, grey to black
Petiole length (mm)	1.5–3.5	3–7
New leaves	bright red	pale green to pink
Leaf length (cm)	1–5	5–9
Leaf width (cm)	0.4–2.6	1.5–4.5
Leaf margins	minutely fimbriate	smooth
Leaf arrangement	alternate spread along stems	pseudo-whorls sometimes alternate, often clustered below buds
Leaf apex	obtuse rarely acute, never acuminate	acute to acuminate
Leaves	usually widest below the middle, narrowly ovate or rarely elliptic	widest at the middle, elliptic to broadly elliptic.
Corolla lobes	erect to spreading, white	recurved, cream
Nectary	prominently toothed (usually 2-toothed)	truncate to rounded or shallowly 3–4 toothed
Bracts and sepals	margins ciliate, dorsal keel indumented	margins ciliate otherwise glabrous
Fruit colour	purple to black	black to bright purple or yellowish
Fruit width (mm)	4–6	6–8

Conservation status: *Trochocarpa montana* has a highly disjunct distribution, being restricted to the higher altitudes in very specific cool and moist environments. The species is known from only seven general locations, and though common at these sites, this taxon is highly susceptible to climate change and changes in fire regimes, both of which are listed as key threatening processes in the *New South Wales Threatened Species Conservation Act 1995* (TSC 1995, 2002, 2004). Thus it is suggested that *T. montana* should be considered vulnerable and listed as such (TSC 1995, 2002, 2004; EPBC 1999).

Etymology: the epithet *montana* refers to the occurrence of all populations at high elevations; it was a manuscript name written on preliminary diagnostic notes on this taxon made by the senior author since 1967. Known colloquially as Mountain Tree-heath.

Acknowledgments

Thanks to Dr Jeremy Bruhl for facilitating access to the N.C.W. Beadle Herbarium at Botany in the University of New England, Armidale. Peter Wilson assisted with the latin diagnosis.

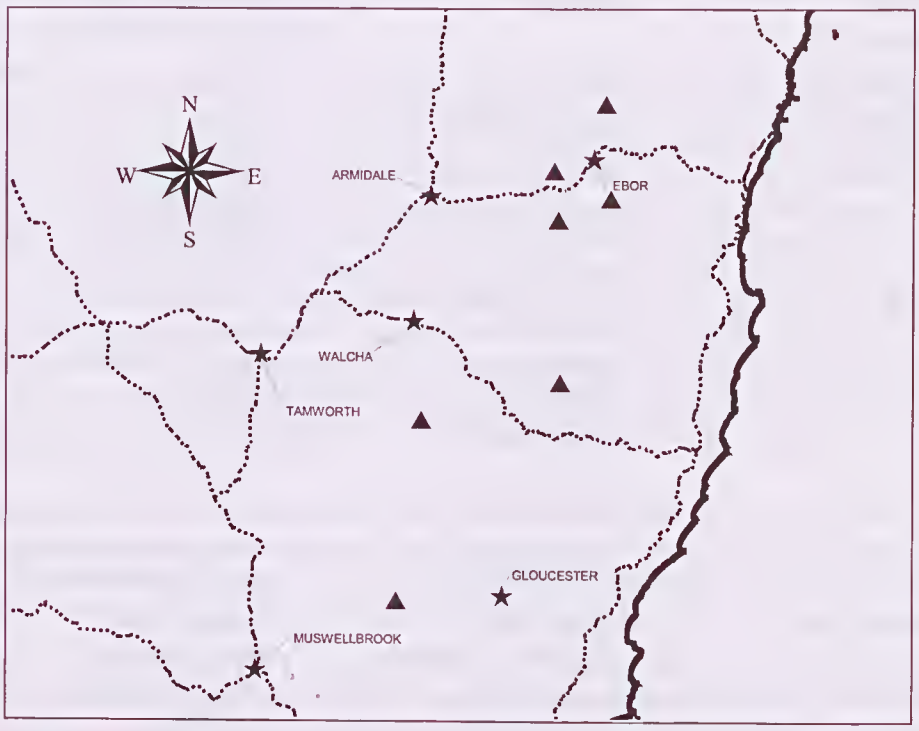

Fig. 1. General distribution map of *Trochocarpa montana* (triangles) in northern New South Wales. ---- Major Roads —— Coastline ★ Towns

References

Clarke PJ, Copeland LM, Noble NE, Bale CL & Williams JB (2000) *The vegetation and plant species of New England National Park.* (Botany, University of New England: Armidale)

EPBC (1999) *Environment Protection and Biodiversity Conservation Act 1999* (http://www.deh.gov.au/epbc/index.html)

Floyd AG (1989) *Rainforest trees of mainland South-eastern Australia.* (Inkata Press: Sydney)

Harden G, McDonald B & Williams JB (2006) *Rainforest trees and shrubs: a field guide to their identification.* (Gwen Harden Publishing: Nambucca Heads)

Hunter JT, Williams JB & Conn BJ (2006) Rediscovery of *Prostanthera staurophylla* F.Muell. and reinstatement of *P. teretifolia* Maiden & Betche (Lamiaceae). *Telopea* 11: 117–126.

Hunter JT (2002) *Vegetation and floristics of Nguiu Nature Reserve.* Report to the New England Region of the New South Wales, National Parks and Wildlife service.

Quinn CJ, Crayn DM, Heslewood MM, Brown EA & Gadek PA (2003) A molecular estimate of the phylogeny of Styphelieae (Ericaceae). *Australian Systematic Botany* 16: 581–594.

TSC (1995) Threatened Species Conservation Act 1995 No 101, in 'In Force Legislation' (http://www.legislation.nsw.gov.au/maintop/search/inforce).

TSC (2002) Threatened Species Conservation Amendment Act 1995 No 78. in 'In Force Legislation' (http://www.legislation.nsw.gov.au/maintop/search/inforce).

TSC (2004) Threatened Species Conservation Amendment Act 1995 No 88. in 'In Force Legislation' (http://www.legislation.nsw.gov.au/maintop/search/inforce).

Wiecek B (1992) *Trochocarpa.* Pp. 433–434 in Harden GJ (ed.) *Flora of New South Wales,* vol. 3. (New South Wales University Press: Kensington)

Williams JB & Hunter JT (2006) *Boronia boliviensis* (Rutaceae series Erianthae), a new rare granite outcrop endemic from north-eastern New South Wales. *Telopea* 11: 260–264.

Williams JB, Harden GJ & McDonald WJF (1984) *Trees and shrubs in rainforests of New South Wales and southern Queensland.* (University of New England: Armidale)

Manuscript received 28 September 2006, accepted 06 March 2007

Telopea 11(4) 419–426

Banksia croajingolensis (Proteaceae) a new species from East Gippsland, Victoria

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Abstract

Banksia croajingolensis Molyneux & Forrester is described and illustrated. Its relationships with *Banksia integrifolia, Banksia marginata* and *Banksia paludosa* are discussed.

Introduction

A new previously unrecorded species of *Banksia* was discovered by the authors in 2000 and identified at the time as *Banksia paludosa*. The new species is distinguished from *Banksia integrifolia, Banksia marginata* and *B. paludosa*, with which it shares certain character states. It is a narrow endemic apparently confined to one drainage line on a coastal heathland in Croajingolong National Park. It is sympatric on its margins with *B. integrifolia* and *B. marginata* but not with *B. paludosa*, which is not recorded for Victoria (Jeanes 1996). This latter species occurs in New South Wales (Harden 2002) with its southern limits on coastal heathlands and nearby forest sites about 35 km to the north-east of the new species. It is further separated from the new species by its position on the north side of the Howe Range and by the extensive Mallacoota Inlet lake system. This system has probably presented a barrier to the migration of plants such as *Banksia* since the last Ice Age. The authors did discover a small population of a dwarfed *Banksia* in June 2006 on an adjoining heathland to the north of the *B. croajingolensis* population which would appear to have some affinities to *B. paludosa*. Its regularly toothed leaf margin is a character shared with *B. paludosa* populations in southern NSW but not with adult foliage of *B. croajingolensis, B. integrifolia* or *B. marginata*. It may suggest either an earlier presence of *B. paludosa* in Victoria or a closer proximity which may have facilitated cross pollination.

Taxonomy

Banksia croajingolensis Molyneux & Forrester ***sp. nov.***

A *B. paludosa* R. Br. foliis integris plerumque obtusis interdum lobatis apicem versus, internodiis brevioribus, a *B. integrifolia* L. f. habitu minore floribus in fructu persistentibus et seminibus ultra unum annum retentis, a *B. marginata* Cav. foliis nec

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semper emarginatis nec truncatis et floribus et infructescentiis minoribus differt. Ab omnibus speciebus indicatis processu florentis basipeto non acropeto differt.

Type: Victoria, Croajingolong National Park, south-western heathland above Shipwreck Creek, c 12 km south-west of Mallacoota, *Molyneux & Forrester s.n.*, 21 June.2006 (holo: MEL 2292847; iso: CANB, NSW)

A mostly small, rarely larger, spreading lignotuberous *shrub* propagating by sexual means and extending asexually by the production of ramets, 35–60(–100) cm tall and 45–120 cm wide. *Branchlets* initially trigonous soon becoming rounded, either glabrous with yellow and red markings or lightly white or rusty pubescent and soon becoming glabrous, nodes crowded. *Leaves* verticillate, sub-verticillate or scattered (more commonly sub-verticillate), narrowly obovate, obtuse, entire or seldom irregularly notched towards apex, shortly apiculate or emarginate, 16–60 mm long, 5–17 mm wide, glabrous above or with early scattered hairs, shiny, primary nerves evident, mid-vein recessed, undersurface appearing white-tomentose, with evident nerves and reticulum; nerves occasionally lightly woolly, mid vein glabrous or less often with a light ferruginous indumentum, margins recurved. *Juvenile ramets* glabrous, stems angular, leaves obovate-cuneate, truncate, emarginate or obtuse, irregularly toothed, sub-verticillate or scattered, 12–55 mm long, 6–8 mm wide. *Conflorescences* cylindrical, terminal or from older wood within canopy, 70–140 mm long, 42–55 mm wide at flowering, basipetalous, shortly pedunculate, basal bracts linear-subulate, ferruginous-tomentose in c. three rows mostly 3(–5) mm long, common bracts ± rhomboidal, white-tomentose or lightly silky-ferruginous, 1.8–2.1 mm across. *Flowers* openly spaced mostly at 90° to rachis, yellow with grey-brown, grey-green or golden pubescence, perianth 15–18 mm long including limb of 3.5 mm perianth c. 0.5 mm wide, tepals twisting, spreading to base, limb acute, pistil slender, glabrous 15–26 mm long including style end, straight or bowed sharply just before anthesis, ovary c. 0.8 mm long with few villous hairs at base, style end not thickened c. 1.5 mm long, about same width as style; spent styles variously at 90° to rachis, straight or relaxed at 70–80° to rachis; old flowers retained for several years. *Infructescences* 90–120 mm long, 35–38 mm wide, follicles elliptical 13–19 mm long, 3–5 mm high, (4–)5–6(–8) mm wide, *Seed* obovate-cuneate, 8–10 mm long, 3–3.5 mm wide, wing 11–12 mm high, 12–13 mm wide. (Fig. 1).

Recommended vernacular: **Gippsland Banksia**

Distribution: apparently endemic to East Gippsland, Victoria, where confined to a single short drainage line draining north from a coastal heathland elevated above the south bank of Shipwreck Creek, c. 12 km SW of Mallacoota. The population of about 480 individuals is confined within the following coordinates: 37°38'98"S, 149°41'63"E (on its southern boundary); 37°38'95"S, 149°41'70"E (on its northern boundary); 37°38'99"S, 149°41'64"E (on its western boundary); 37°38'95"S, 149°41'65"E (on its eastern boundary).

Habitat: *Banksia croajingolensis* is emergent from mixed coastal heathland vegetation in moist sandy soils associated with *Acacia suaveolens, Allocasuarina paludosa, Babingtonia pluriflora, Epacris impressa, Hakea teretifolia, Patersonia occidentalis, Persoonia laevis, Xanthorrhoea resinosa* and various sedges and rushes. Both *B. integrifolia* and *B. marginata* are sympatric on the margins of the *B. croajingolensis* stand. *Banksia marginata* tends to be a sub-shrub within or just emerging from the dense heathland canopy on the eastern margins of the stand whereas *B. croajingolensis* is always emergent. It is strongly

Fig. 1. *Banksia croajingolensis* illustrating variation in bud colour, basipetalous flowering sequence, the mostly sub-verticellate leaf arrangement, evident nerves and reticulum on lower leaf surface, and mature infructescences with retained seed.

sympatric with *B. integrifolia* on its western margins and on the edges of woodland containing *Banksia serrata, Eucalyptus sieberi* and an undescribed eucalypt with affinity to *E. globoidea*. On its northern boundary it is sympatric with apparent hybrid swarms including *B. integrifolia* and an unknown second parent.

The underlying geology is strongly banded and distorted mudstone and slates of Ordovician origin.

Etymology: the specific epithet commemorates the Gunai/Kurnai Nation name for the region from which the species is currently known. The original name Krowathunkoolong was adapted in the early days of European settlement to Croajingolong, the name of the county to which the new species is apparently endemic. The epithet 'croajingolensis' is a euphonic contraction of the less appealing 'croajingolongensis' as suggested by Johnson and Hill (1990) when they described *Eucalyptus croajingolensis*.

Conservation Status: using the IUCN Red List Categories and criteria (IUCN 2001), the new species is assessed as Vulnerable with a conservation code of VU D1+2 on account of its small population size, very restricted area of occupancy and restriction to a single location.

Representative specimens examined: Victoria: Croajingolong National Park, above Shipwreck Creek, [ca. 12 km SW of Mallacoota], *Molyneux & Forrester*, 24 Aug 2005 (MEL 2292848, MEL 2292849, MEL 2292856); ibid., 17 vi 2006, (MEL 2292860, MEL 2288265).

Discussion

The new species differs from *B. paludosa* in having entire mostly obtuse leaves with occasional lobing toward the apex, and much shorter leaf internodes; from *B. integrifolia* which is a large shrub or small tree which sheds its flowers following anthesis and with seed dehiscing usually within one year; and from *B. marginata* which has consistently truncate and often emarginate leaves, and much smaller flowers and generally much smaller conflorescences and infructescences.

It differs from all of the above three species in being basipetalous, not acropetalous, in its flowering sequence. This difference in flowering sequence raises questions as to the classification of *B. croajingolensis* within Banksia. In all states other than flowering sequence, it nests within section *Banksia* of subgenus *Banksia* (species with straight style ends). This sequence is common in the eastern species *B. ericifolia* and the *B. spinulosa* group and a number of Western Australian species in series *Spicigerae* of section *Oncostylis* and with *Banksia quercifolia* and *Banksia oreophila* which form series *Quercinae* of section *Banksia*. When considering the basipetaous sequence of flowering in *B. croajingolensis* compared with other species in section *Banksia*, it may be necessary to consider also whether a basipetal sequence implies a broader relationship to other taxa sharing this feature. As this flowering sequence is shared across different series and sections of subgenus *Banksia* across southern Australia, it is possible that they arose spontaneously and independently of other groups' genetic input.

The flowering sequence anomaly in *B. croajingolensis* compared with other members of series *Banksiae* of section *Banksia*, with which it otherwise shares many character states, may require it to be recognized in a new series.

The table of comparison with *B. croajingolensis* (Table 1) includes close regional forms of *B. integrifolia* and *B. marginata* and southern New South Wales forms of *B. paludosa* from similar coastal or near coastal localities. These are all members of *Banksia* series *Banksiae*. Whilst *B. integrifolia* and *B. marginata* are sympatric with the new species, the *B. paludosa* collections used for comparison are from heathland and woodland populations in Nadgee Nature Reserve and Green Cape in south-eastern New South Wales. *Banksia serrata* was not included as a comparator as it is a member of *Banksia* series *Orthostylis* [and apparently not implicated in the ancestry of *B. croajingolensis*]. It would appear from both physical observations and morphometric measurements that *B. integrifolia, B. marginata* and *B. paludosa* have influenced the development of *B. croajingolensis* and that this species may have resulted from various crossings and back crossings between them. In seedling trials conducted from 2006 to 2007, there was no apparent segregation in the offspring of *B. croajingolensis*. It is genetically segregated from the other three species because it is self perpetuating and clonal, and forms a substantial population. This cannot be said of the other three species as it can be demonstrated that there is clear hybridization between all of them, which has resulted in long standing confusion regarding the identity of certain specimens.

Over approximately eight years of field study on the banksias of south-eastern NSW and far eastern Victoria from Green Cape in NSW to Shipwreck Creek and Sandpatch heathlands in Victoria, the authors have noted a number of these apparent hybrid swarms.

In 1972 one of us (WMM) collected seed of a 'robust' *B. paludosa* among typical specimens on the middle south-west slopes of Green Cape. The few progeny which resulted from their germination appeared to share characters of *B. paludosa* and *B. integrifolia*, which are closely related.

In 2004 the authors discovered a small population of a large spreading banksia up to ± 2 m tall on the lower south-west slopes of Green Cape. This small stand grew sympatrically with both dwarfed *B. paludosa* and small tree forms of *B. integrifolia*.

Investigations of major characters such as branchlet indumentum, leaf undersurface indumentum, flower colour, the degree of spent flower retention and of long or short term seed retention, indicated that these stands should be regarded as hybrids between the two species.

During field work at Impressa Moor in Nadgee Nature Reserve with Head Ranger Lyn Bell, we found distinct variations in specimens which we had at first thought were either *B paludosa* or *B. marginata*. We recorded character states in these plants which appeared to be intermediate between these two species. Some of these are not unlike the small population with affinities to *B. paludosa* which the authors collected in June 2006 on the northern heathland above Shipwreck Creek (about 50 plants ± 35 cm tall x 40 cm wide). The Impressa Moor population was growing sympatrically with the local small heathland form of *B. marginata*.

In the region south west of Mallacoota putative hybrid swarms between *B. integrifolia* and *B. marginata* are not uncommon. Large but rounded *B. integrifolia*-like plants co-exist with more typical upright narrow forms, but while the latter shed old flowers and seed at an early stage, some specimens of the former retain both flower and seed over a long period. The influence here would seem to be *B. marginata* as it is to the south of the nearby Mallacoota Aerodrome on the margin of *Melaleuca armillaris* stands.

Table 1. Comparison between *B. croajingolensis, B. marginata, B. paludosa* and *B. integrifolia*.

Character	*B croajingolensis*	*B marginata*	*B paludosa*	*B integrifolia*
Habit				
Size	Mostly small	Small	Small to medium	Medium to tall
Shape	Spreading	Spreading	Spreading	Upright
Branchlets				
Indumentum	Glabrous or initially pubescent, soon glabrescent	Villous, often into third year	Glabrous	Villous, often into second year
Colour	Red or yellow	Green	Red or yellow	Green, often becoming yellow or red
Leaves				
Shape	Narrowly obovate	Linear to oblong	Lanceolate to obovate	Broadly or narrowly obovate
Margin	Seldom irregularly notched towards apex	Entire	Dentate	Entire in adult phase
Apex	Obtuse, shortly apiculate or emarginate	Truncate, often emarginate	Obtuse	Obtuse
Phyllotaxis	Verticillate, sub-verticillate or scattered	Alternate, scattered	Verticillate	Verticillate
Node to Node length	Short	Short	Widely spaced	Mostly widely spaced
Adaxial surface	Glabrous, shiny	Hirsute dull, becoming glabrous	Glabrous, glossy	Glabrous, shiny when young
Abaxial surface	White woolly but with main nerves and reticulum evident	White woolly, nerves not visible reticulum evident	Appearing green with prominent, main nerves and reticulum, with white woolly indumentum in reticulum pits, occasionally encroaching on the reticulum	Woolly white, main nerves and reticulum not visible
Margins	Recurved	Recurved to revolute	Recurved	Recurved
Length	16–60 mm	12–42 mm	40–130 mm	26–100 mm
Width	5–17 mm	3–9 mm	15–35 mm	7–20 mm
Conflorescence				
Shape	Cylindrical	Cylindrical to marginally ovoid	Cylindrical	Cylindrical
Position	Terminal on branchlets and older wood, often subtended by branchlets	Terminal on branchlets or older wood and often subtended by branchlets	Terminal or more often on older wood	Terminal on or older wood and often subtended by branchlets

Character	*B croajingolensis*	*B marginata*	*B paludosa*	*B integrifolia*
Height	70–140 mm	40–70 mm	70–130 mm	110–150 mm
Width at flowering	42–55 mm	45–47 mm	45–50 mm	60–70 mm
Flowers				
Arrangement on rachis	Open	Close	Open	Close
Colour in bud	Yellow with a grey brown, grey green or golden pubescence	Lemon with grey pubescence	Yellow with golden brown pubescence	Yellow with a white pubescence
Sequence	Basipetalous	Acropetalous	Acropetalous	Acropetalous
Style				
Posture prior to anthesis	Straight or bowed	Bowed	Straight or slightly bowed	Bowed
Colour	Yellow	Pale yellow	Yellow	Pale yellow
Length	15–26 mm	20–31 mm	17–20 mm	27–32 mm
Infructescence				
Height	90–120 mm	45–50 mm	75–110 mm	75–85 mm
Width	35–38 mm	28–30 mm	40–45 mm	28–32 mm
Seed				
Shape	Obovate cuneate	Falcate cuneate	Obovate falcate	Narrowly obovate cuneate
Length	8–10 mm	5–7 mm	7.5–8 mm	8–9 mm
Width	3–3.5 mm	3 mm	3.5 mm	3.5–4 mm
Wing Length	11–12 mm	7–9 mm	9–10 mm	10–11 mm
Wing Width	12–13 mm	8–9 mm	10–12 mm	6–8 mm

All colour coding 1986 Edition RHS Swatch.

Unfortunately, in many instances specimens of these swarms have been assigned indiscriminately to either *B. integrifolia* or *B. marginata*. This suggests that further detailed study of all *Banksia* populations within this region is needed. The anomalous habitat of *B. integrifolia* on the lower middle reaches of the Betka River, where it grows as a rheophytic chasmophyte, warrants investigation. *Banksia integrifolia* is also recorded from the lower reaches of the Genoa River gorge many kilometres upstream from the coast.

Acknowledgments

Gippsland has been a botanical 'happy hunting ground' for the authors for more than thirty years, and certain people have been consistent supporters or critical reviewers of papers by one of us (Molyneux) on numerous occasions. David Cameron, Victorian Department of Sustainability and Environment, has contributed greatly to this paper with discussions on an appropriate epithet and common name, the paper's structure, and its editing. Neville Walsh (National Herbarium of Victoria - MEL) assisted with the structure of the paper with a range of modifications and supplied the Latin diagnosis.

Peter Weston (National Herbarium of New South Wales) made several worthwhile suggestions on clarifying the taxon, while Bob Semmens (Mallacoota) made several seasonal collections and observations for us. Thanks also to Lyn Bell (Head Ranger) for access to Nadgee Nature Reserve and for driving one of us (Molyneux) to Impressa Moor, and to Jackie Miles for her observations and assistance with field work on that day. The authors also thank the staff of MEL for access to collections and to the library.

In addition, we wish to thank Grattan Mullett, Co-ordinator Krowathunkooloong Keeping Place, Bairnsdale, Victoria, Graham Thorpe, Chairperson of the Gurnai/ Kurnai Instructing Committee and the Bidawal People for their support regarding the use of the name *croajingolensis* as the epithet for this new taxon.

References

Harden GJ (2002) *Banksia*. Pp. 82–86 in Harden GJ (ed.) *Flora of New South Wales,* revised edition, vol. 2. (New South Wales University Press: Kensington)

IUCN (2001) IUCN Red List Categories: Version 3.1. Prepared by the IUCN Species Survival Commission. (IUCN: Gland & Cambridge)

Jeanes JA (1996) *Banksia*. Pp. 882–887 in Walsh NG & Entwisle TJ (eds) *Flora of Victoria*, vol. 3. (Inkata Press: Melbourne)

Johnson LAS & Hill KD (1990) New taxa and combinations in *Eucalyptus* and *Angophora*. *Telopea* 4: 37–108.

Manuscript received 15 January 2007, accepted 08 March 2007

Telopea 11(4) 427–436

The identity of *Cassinia uncata* A.Cunn. (Asteraceae: Gnaphalieae)

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Abstract

Cassinia uncata A.Cunn. was described from over-mature incomplete material, and its identity has been a long-standing source of confusion. The name has been misapplied to at least 27 different species of *Cassinia* and one of *Haeckeria* by many authors, and far from being the widespread and common species of much Australian literature, *C. uncata* is shown to be rare and possibly vulnerable, and confined to inland New South Wales and South Australia. A lectotype and an epitype are chosen for *C. uncata* and a full description and list of existing specimens is provided.

Introduction

In June 1823, on a journey north from Bathurst, Allan Cunningham stood at the summit of Pandoras Pass through the Liverpool Range and looked down on to the Liverpool Plains. Short of food, he had no time to explore this area, but his glowing report led to rapid expansion of settlement and follow-up expeditions by Oxley and others.

On 29 March 1825 Cunningham left Parramatta and again visited the Liverpool Plains district. He crossed Pandoras Pass in April 1825 and descended on to the plain itself, following the course of Coxs Creek north from about the present site of Bundella almost to Boggabri. Somewhere in this traverse of the Liverpool Plains he collected several specimens of a shrubby asteraceous plant, which had finished flowering but still retained a few old heads.

In 1827 Cunningham returned to the Liverpool Plains district for a further expedition north to the Brisbane River, during which he was to discover the Darling Downs (McMinn 1970). In early May 1827 he crossed the eastern end of the Liverpool Plains, following the Mooki River, near the present town of Breeza. It is possible that he again saw and perhaps collected the same plant.

In 1834 he wrote to A.P. de Candolle describing this plant, and providing a duplicate of one of his specimens. De Candolle included this description in the Prodromus

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(Candolle 1838), attributing it to Cunningham: "in dumetis siccis ad partem occid. planitierum Liverpool maio fere deflor. legit A. Cunningham. Species quoad flores incompletos dubia, sed ex foliis distinctissima, nunc in hort. kew culta (v.s. sp. etc.)". Cunningham and de Candolle were wise to describe this plant as 'dubia', because the poor description, composed mainly of vegetative characters, and the fragmentary type collections subsequently led to complete confusion as to the identity of *C. uncata*.

Bentham (1867) reduced Cunningham's species to a variety of *C. aculeata* (*C. aculeata* var. *uncata* (A.Cunn.) Benth.), citing 'Liverpool plains, A.Cunningham; Clarence river, Beckler; also in Leichhardt's collection". This action by Bentham, along with his reduction of *C. adunca* to synonymy under *C. aculeata* triggered doubt on the application of the name *C. uncata* in the minds of all subsequent authors, because these three taxa represent three different sections of the genus (see below). For the next 140 years *Cassinia* was viewed by many as a 'difficult' genus, and some even suggested that it might be congeneric with *Ozothamnus*. This last idea was challenged by Orchard (2004a, 2005). The white-headed shrubby species of the drier and semiarid regions of SE Australia were considered particularly difficult and variable, and while some (*C. longifolia*, *C. aculeata*, *C. laevis*, *C. dentata*) were recognised fairly readily, the tendency was to treat all plants with white heads and more or less hooked leaf tips as 'C. uncata'.

Orchard (2004a) showed that *Cassinia* was far more speciose than had been recognised previously, and provided a framework of infrageneric taxa to accommodate the variation within the genus. The two subgenera recognised were distinguished on inflorescence characters, while the sections within subg. *Cassinia* (the larger of the two) were distinguished principally on achene characters. The two sections within subg. *Achromolaena* were separated on inflorescence shape and structure.

With this framework in place it was possible to begin understanding the complicated patterns of misapplication of the name *C. uncata* A.Cunn. Putative type material was found in MEL, K (2 sheets) and G (seen only on microfiche). Immediately a number of problems became apparent. All of Cunningham's collections were made late in summer/autumn, when flowering and fruiting was almost over. The few remaining flower heads are disintegrating, and there are few fruits and no flowers available. However, the inflorescence shape is more or less conical, with mainly alternate capitula, which places the species in subg. *Achromolaena* sect. *Achromolaena*. Cunningham in de Candolle (1838) had referred to the lack of flowers, but commented on the distinctive leaves. This is certainly so: the tips of the linear leaves are abruptly reflexed at 90°, and slightly expanded at the bend, producing two bullate bulges. The deltoid apiculum formed by extension of the midrib, and found in many *Cassinia* species, is present, but well beyond the point of flexure. When this leaf shape was compared with most other specimens that had been referred to *C. uncata*, it was found that these other specimens mainly had gradually reflexed leaf tips, not the slightly flattened and abrupt bend of true *C. uncata*. In addition, many of the plants previously determined or described as 'C. uncata' had flat-topped inflorescences composed of compound dichasia, diagnostic of subg. *Cassinia*. In fact only a handful of collections made since Cunningham's original discovery (from near Coolabah, Gilgunnia, Euabalong West and Condobolin in New South Wales and from Danngali Conservation Park in South Australia) could be confidently matched to his type specimens.

A second problem was that the Cunningham specimen in G, de Candolle's herbarium, is numbered 67, while others in MEL and K are unnumbered or numbered 95, suggesting

that Cunningham may have made more than one gathering. Fortunately, all putative syntypes are of the same species, with its distinctive leaf tips.

In February 2004 I made a number of flowering collections from the Breeza State Forest on the south-eastern margins of the Liverpool Plains, and these closely matched Cunningham's original collections of *C. uncata*. They were growing in association with plants of *Cassinia laevis*, and closely resembled them in many respects, but differed in having slightly more yellowish inflorescences, and were flowering a few weeks earlier. The leaf tips of *C. laevis* are almost straight, or if recurved only gently so, quite different to those of *C. uncata*. When fresh there is also a subtle difference between the two species in the aromatic resinous smell of the leaves. It is perhaps noteworthy that Cunningham also collected *C. laevis* (*A.Cunningham 58*, 1825, Liverpool Plains (MEL 221269 & 1583046)) near this spot in 1825 and obviously noted that it was different to his *C. uncata*. Subsequently, additional collections of *C. uncata* were made by me west of Nyngan, near Pangee and between Nymagee and Gilgunnia, all in New South Wales. These collections have made it possible to provide an expanded description of *C. uncata*, and to designate an epitype (with duplicates) to provide improved reference material for this rare species.

As mentioned earlier, the name *C. uncata* has been persistently and widely misapplied to a number of other species. Only some of the more important of these are discussed below. This enumeration is not intended to be critical in any way of the authors involved: the confusion introduced by Bentham and the fragmentary type material made it inevitable that the name would be misapplied until a full revision of the genus was undertaken. The usages of subsequent authors reflected contemporary views, but unfortunately also disguised the fact that *Cassinia* was far more speciose than previously suspected. Once the identity of *C. uncata* is settled, the rest of the genus becomes far more easily understood. The reputation of *Cassinia* for being 'difficult' stems almost entirely from the confusion surrounding *C. uncata* and the medium-sized white-headed taxa of the semiarid of New South Wales, Victoria and South Australia. The history below is intended only to emphasise the scale of confusion over the past 140 years, and to provide an indication where possible of the taxa involved.

Bentham (1867) reduced *C. uncata* to a variety of *C. aculeata*, a placement that cannot stand. *Cassinia aculeata* is the type species of the genus and of subg. *Cassinia* and sect. *Cassinia*, while *C. uncata* belongs in *Cassinia* subg. *Achromolaena* sect. *Achromolaena*. Bentham included in his *C. aculeata* var. *uncata* collections by Beckler from the Clarence River, and others by Leichhardt. The Beckler collections have not been located but two specimens of depauperate *C. cunninghamii* in the Mueller herbarium (MEL 1582832 & 221360) may be the ones referred to, while the Leichhardt collections were *C. lepschii* (sect. *Costatae*). As a footnote to *C. aculeata* (incl. var. *uncata*), Bentham referred to specimens collected by Mueller at Macalister River. These are *Cassinia nivalis*. The specimens "from other parts of Victoria" with "involucral bracts more or less distinctly superposed in 4 or 5 rows" are *C. complanata* and *C. diminuta*.

Wakefield (1951) reinstated *C. uncata* as a species distinct from *C. aculeata*, believing that it extended from Wallangarra in Queensland throughout eastern New South Wales (including the alps), and scattered across Victoria especially in Gippsland. Wakefield believed that *C. complanata* was closely related, but probably distinct. His concept of *C. uncata* thus included at least *C. lepschii*, *C. copensis*, *C. ochracea*, *C. nivalis* and probably *C. wyberbeusis* and *C. heleniae* all from sect. *Costatae*, *C. maritima*, *C. monticola*,

C. hewsoniae and *C. theresae* from sect. *Complanatae*, and perhaps some forms of *C. aculeata* (sect. Cassinia) and *C. longifolia* (sect. Longifoliae).

Willis (1967) reduced *C. complanata* to a synonym of *C. uncata*, a position that he maintained in the *Handbook to Plants in Victoria* (Willis 1973). In the latter publication he gave the distribution of *C. uncata* in Victoria as "Gippsland valleys, Warby Range, Goulburn R. to Bendigo district, Kerang, Little and Big Deserts", thus including plants now known as *C. longifolia* (Gippsland valleys) from ser. *Longifoliae*, possibly *C. aculeata* and an undescribed related species (Gippsland - sect. *Cassinia*), *C. scabrida* and possibly *C. ozothamnoides* (Warby Range - sect. *Venustae*), *C. diminuta* (Goulburn R. to Bendigo district and Kerang) and *C. complanata* (Little and Big Deserts) — both from sect. *Complanatae*, and probably a still-undescribed species from Little Desert (sect. *Achromolaena*). As Willis (1973) also included NSW and the ACT in the distribution of *C. uncata*, by implication he also included some of the other species mentioned above for Wakefield (1951).

Burbidge and Gray (1970) accepted *C. uncata* (including *C. complanata*) with a similar circumscription to that of Willis (1973), a species that they considered extended from Queensland to South Australia. However, they stated that in the ACT region it was most common in the Kosciuszko region and the Victorian Alps, and their concept thus mainly embraced *C. monticola* (sect. *Complanatae*) and *C. ochracea* (sect. *Costatae*). It may also have included *C. hewsoniae* (sect. *Complanatae*) which just reaches the ACT.

Beadle, Evans and Carolin (1972) included *C. uncata* in their catalogue of the plants of the Sydney region, but it is not clear just what they included in their broadly circumscribed taxon. Candidates are the narrow-leaved form of *C. longifolia* (ser. *Longifoliae*) and *C. accipitrum* (sect. *Leptocephalae* ser. *Compactae*). Beadle (1980) used a virtually identical description of *C. uncata* in his treatment of a broadly defined *C. uncata* in northeastern New South Wales. In this case, the taxa encompassed included *C. cunninghamii*, *C. macrocephala*, *C. compacta*, *C. telfordii* and *C. straminea* (all sect. *Leptocephalae*) as well as *C. lepschii*, *C. copensis*, *C. ochracea* and probably *C. wyberbensis* and *C. heleniae* from sect. *Costatae*.

Cunningham et al. (1981) probably included elements of true *C. uncata* in their concept of *C. uncata*, but their description included characters such as "very sticky shrub" and "flower heads with 4-8 flowers" which suggested a mixed concept, including *C. hewsoniae* and (although it does not occur in western N.S.W.) *C. complanata* (both sect. *Complanatae*).

Eichler (1965) unfortunately confused *C. punctulata* with *C. complanata*, adopting the first name for the South Australian/Victorian species, and hinting that both should be considered synonymous with *C. uncata*. *Cassinia punctulata* was later shown to be a *Haeckeria* species by Orchard (2004b). However Jacobs and Pickard (1981) took up Eichler's suggestion, and incorrectly treated *C. aculeata* var. *uncata*, *C. complanata* and *C. punctulata* as synonyms of *C. uncata*.

Stanley (1986) recorded *C. uncata* from south-eastern Queensland, misapplying the name to species now known as *C. wyberbensis*, *C. copensis* and *C. lepschii* (all sect. *Costatae*).

Cooke (1986) recorded *C. uncata* for South Australia, noting that it was variable. In this work the name *C. uncata* is misapplied to *C. complanata*, *C. adunca* and

C. tegulata. Ironically, although true *C. uncata* does occur in South Australia, in Danngali Conservation Park north of the River Murray, Cooke was probably unaware of it from that locality, as all specimens were on loan to the present author at the time, under a different name. Cooke confirmed that *Haeckeria punctulata* was distinct from *Cassinia*.

Everett (1992) also adopted a very broad circumscription of *C. uncata*, probably including true *C. uncata* along with many taxa from sect. *Costatae* (especially *C. copensis*, *C. lepschii*, *C. ochracea*), sect. *Leptocephalae* (especially *C. accipitrum*) and sect. *Complanatae* (especially *C. theresae*, *C. maritima* and probably *C. hewsoniae*) in particular, but also including a still-undescribed species from subg. *Achromolaena*.

Puttock (1999) incorrectly recorded *C. uncata* from Victoria, noting that it apparently had several variants. In this work, the name *C. uncata* is misapplied to *C. complanata*, *C. diminuta*, *C. maritima* and *C. monticola* (all sect. *Complanatae*), and to *C. ochracea* and *C. nivalis* (sect. *Costatae*). In this work Puttock also placed in synonymy "*Cassinia arcuata* var. *uncata*", an erroneous reference to *Cassinia aculeata* var. *uncata*.

In summary, the name *Cassinia uncata* has been misapplied, in whole or in part, at one time or another, to all of the following species (see above for details):

Haeckeria F.Muell.:

Haeckeria punctulata (F.Muell.) J.H.Willis

Cassinia R.Br.:

Cassinia sect. *Complanatae* Orchard: *C.* × *adunca* F.Muell. ex Sonder (*C. complanata* × *C. tegulata*), *C. complanata* J.M.Black, *C. diminuta* Orchard, *C. hewsoniae* Orchard, *C. maritima* Orchard, *C. monticola* Orchard, *C. tegulata* Orchard, *C. theresae* Orchard.

Cassinia sect. *Venustae* Orchard: *C. ozothamnoides* (F.Muell.) Orchard, *C. scabrida* Orchard.

Cassinia sect. *Leptocephalae* Orchard: *C. accipitrum* Orchard, *C. compacta* F.Muell., *C. cunninghamii* DC., *C. macrocephala* Orchard, *C. straminea* (Benth.) Orchard, *C. telfordii* Orchard.

Cassinia R.Br. sect. *Cassinia*: *C. aculeata* R.Br., *C. longifolia* R.Br. and a currently undescribed species from southern Victoria.

Cassinia sect. *Costatae* Orchard: *C. copensis* Orchard, *C. heleniae* Orchard, *C. lepschii* Orchard, *C. nivalis* Orchard, *C. ochracea* Orchard, *C. wyberbensis* Orchard.

Cassinia sect. *Achromolaena* Orchard: Two currently undescribed species, one from Victoria and one from New South Wales.

Typification and description

Cassinia uncata A.Cunn. in DC., Prodr. 6: 156 (1838)

Type citation: "In dumetis siccis ad partem occid. Planitierum Liverpool maio fere deflor. legit cl. A.Cunningham."

Lectotype (designated here): *A. Cunningham 95*, May 1825, bushy tracts on the

Western side of Liverpool Plains, N. S. Wales, K!. Isolectotypes: *A. Cunningham 95*, s. dat., Shrub 5 f. high. W. skirts of Liv. Plains, K!; *A. Cunningham 95*, s. dat., NSW (MEL 221362!). Residual syntype: *A. Cunningham 67*, Liverpool Plains, G (seen microfiche). **Epitype (designated here):** New South Wales, North Western Slopes, 6 km along Spring Ridge road, c. 8 km due W of Breeza, *A.E. Orchard 7196 & T.A. Orchard*, 12 Feb 2004, NSW! Duplicates of epitype in AD!, CANB!

Erect shrubs 1–2 m tall, to 1 m diam., with faint resinous smell; older branches with light brown bark becoming slightly fissured longitudinally; young twigs olive brown with a dense indumentum of white woolly hairs with occasional emergent spreading multiseriate hairs 0.1–0.2 mm long and occasionally gland-tipped, rarely absent, and sparse subsessile globular hairs. Leaves alternate, spreading, not decurrent, sessile, narrowly linear to terete, 6–12 (–15) mm long, 0.5–1.0 mm wide; upper surface mid-green, dull, rugose, glabrous and sometimes somewhat viscid above; lower surface obscured by margins revolute to midrib, covered (including midrib) with (at least in proximal part) dense woolly hairs and underlying subsessile globular glandular hairs; midrib sunken above, prominent below; tip truncate, slightly flared (bullate) and abruptly reflexed, with a deltoid apiculum. Inflorescence a subconical dense head of 25–100 capitula arranged ± alternately along the branched inflorescence axes, the uppermost capitula sometimes subdichasial. Capitula 3.0–3.5 mm long, tapering to base, appearing off-white to cream from a distance, with phyllaries white tipped and green below. Receptacle small, flat to slightly elongate. Phyllaries 18–20, all papery, spirally arranged in 4–6 whorls, or sometimes somewhat vertically ranked. Outermost phyllaries tiny, ± orbicular, green hyaline, 0.5–0.6 mm long, glabrous. Inner phyllaries narrowly oblong to narrowly ovate, 2.3–3.0 mm long, 0.7–1.1 mm wide, blunt; stereome green, becoming golden brown, glabrous apart from a few subsessile globular hairs; lamina wing narrow (c. 0.1–0.2 mm), hyaline; lamina tip opaque creamy white, with a green hyaline section below. Paleae 2.4 mm long, 0.6 mm wide, similar to inner phyllaries but more lanceolate, tapering to an acute slightly lacerate tip, with stereome less developed. Pappus of 17–18 flattened bristles, fused at extreme base, barbellate on margins, slightly swollen at tip; cells at tip clavate, obtuse. Corolla greenish cream; tube (1.4–) 1.5–2.0 mm long, tapering to base, 0.4–0.5 mm diam. at throat, 0.1 mm diam. at base, swollen around stylopodium; lobes deltoid, spreading, glabrous, c. 0.4 mm long. long and about as wide as the thecae; tails short; filament collars 0.28–0.30 mm long, golden yellow. Style c. 2 mm long plus reflexed arms c. 1 mm long, with a terminal stigmatic brush. Stylopodium small, almost smooth, depressed globular. Ovary shortly cylindrical, 0.5–0.6 mm long, 0.25 mm diam., golden brown, with sparse to moderately dense biseriate gland-tipped hairs c. 0.1 mm long; carpopodium small, white. Fruit not seen fully mature, olive brown to blackish, spindle shaped, 0.6–1.0 mm long, with sparse semiappressed biseriate gland-tipped hairs; pappus shed as a ring of bristles (Fig. 1 a–v).

Distribution: confined to the North Western Slopes, Central Western Slopes, North Western Plains and South Western Plains districts of New South Wales, with an outlier in the northern Murray district of South Australia. Previous records from Victoria, Queensland and districts of New South Wales and South Australia other than those listed above, are erroneous (Fig. 2).

Ecology: found in dry open woodland dominated by mallee *Eucalyptus*, Casuarinaceae, *Callitris* and shrubby *Acacia* spp., often on sandy or loam soils with flat or undulating topography. Most populations are small and localised, and seed set seems to be poor.

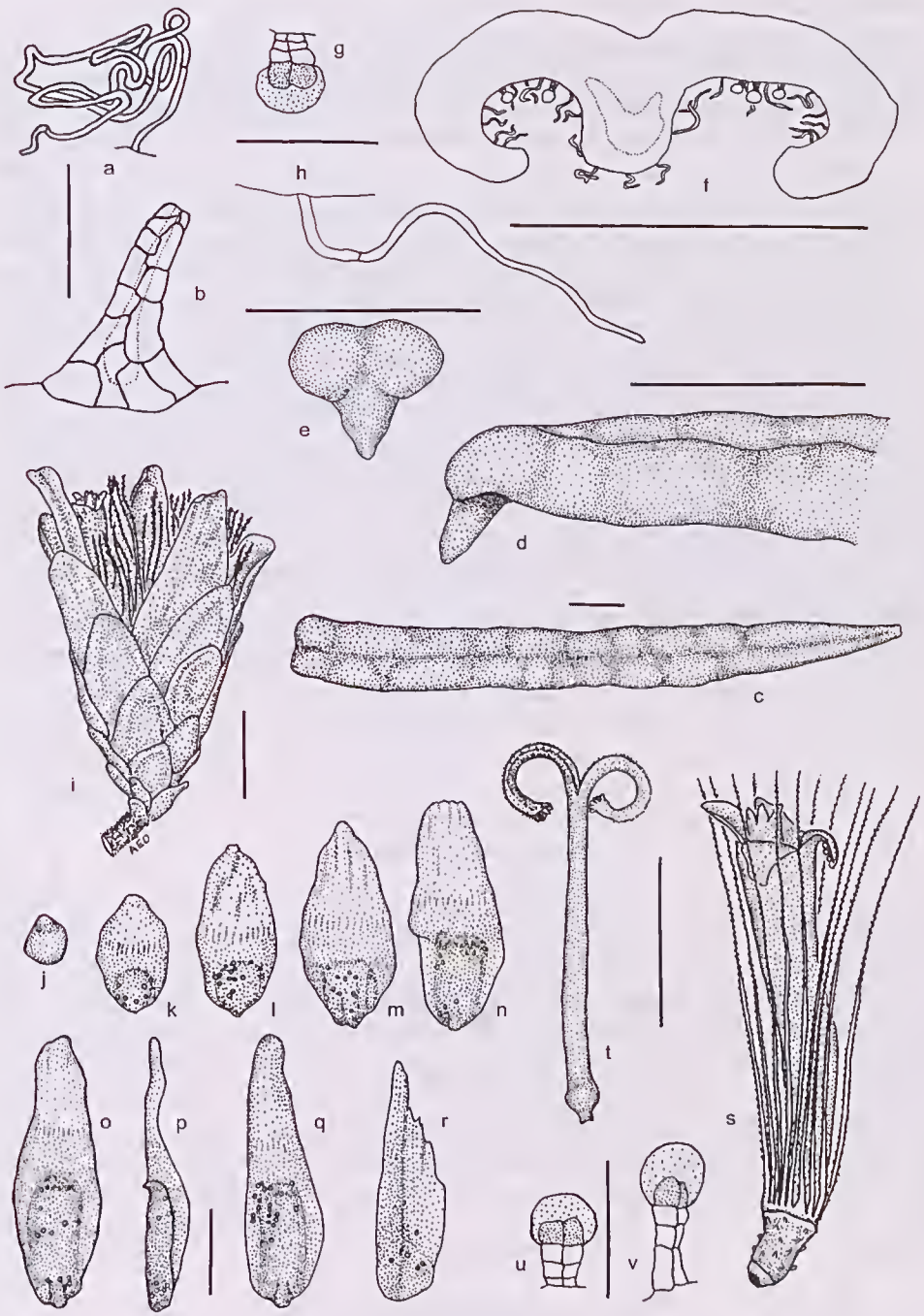

Fig. 1. *Cassinia uncata.* **a,** woolly stem hair. **b,** multiseriate stem hair. **c,** mature leaf, adaxial surface. **d,** leaf, lateral view of tip. **e,** leaf, end-on view of tip. **f,** leaf semidiagramatic transverse section. **g,** subsessile globular hair from undersurface of leaf. **h,** woolly hair from undersurface of leaf. **i,** capitulum. **j–q,** involucral bracts in abaxial view, series from outer to inner (p is a lateral view of o). **r,** palea. **s,** floret. **t.** style. **u, v,** biseriate gland-tipped hairs from ovary. All drawn from *R.N.Peacock s.n.*, NSW 13922. Scale bars represent 0.1 mm (a, b, g, h), or 1 mm (c–f, i–v).

Flowering occurs from February to March.

Specimens examined: South Australia: Murray: Danggali Conservation Park, *Conrick 713*, 29 Feb 1982 (AD, HO, MEL); Danggali Conservation Part, S of Birthday Dam, N of Smiths Dam, *Cunningham 569 & Moore*, 3 Mar 1993 (AD, CBG, STU); 9.5 km due S of Canopus HS, *Williams 7743*, 24 Feb 1976 (AD). **New South Wales:** North Western Slopes: 6 km along Spring Ridge road, c. 8 km due W of Breeza, *Orchard & Orchard 7195*, 12 Feb 2004 (AD, BRI, CANB, MEL, NSW); loc. cit., *Orchard. &.Orchard 7197*, 12 Feb 2004 (AD, BRI, CANB, NSW); loc. cit., *Orchard & Orchard 7199*, 12 Feb 2004 (CANB, MEL, NSW). Central Western Slopes: Condobolin, *Maiden s.n.*, 1888 (NSW 13921). North Western Plains: 18 km from Buddabadah on road to Nymagee, *Orchard & Orchard 7225*, 14 Feb 2004 (AD, BRI, CANB, MEL, NE, NSW); Peisley State Forest, 45 km from Buddabadah on road to Nymagee, c. 1 km W of Pangee, *Orchard & Orchard 7229*, 14 Feb 2004 (AD, CANB, NSW); loc. cit., *Orchard & Orchard 7230*, 14 Feb 2004 (AD, CANB, NSW); Coolabah, *Peacock s.n.*, 1900 (NSW 13922). South Western Plains: Gilgunnia, *Bauerlen 3190 p.p.*, Feb 1900 (NSW 445755); Gilgunnia, *Bauerlen 3190 p.p.*, Feb 1904 (AD 118634 & 118635, BRI, NSW 3190, 13920 & 437909); 4 km W of Euabalong West along railway line, *Cunningham & Milthorpe 5367*, Feb 1978 (NSW); Nymagee-Gilgunnia road, 15 km from Nymagee, *Orchard & Orchard 7231*, 14 Feb 2004 (AD, CANB, MEL, NSW); 7 km NE of Gilgunnia on Nymagee road, *Orchard & Orchard 7232*, 14 Feb 2004 (AD, BRI, CANB, NSW); 2 km SW of Gilgunnia Rest Area on Kidman Highway, *Orchard & Orchard 7233*, 14 Feb 2004 (AD, BRI, CANB, MEL, NSW).

Note: the authorship of this species name is often cited as *C. uncata* A.Cunn. ex DC. However, as de Candolle clearly stated that the description of the plant was based on

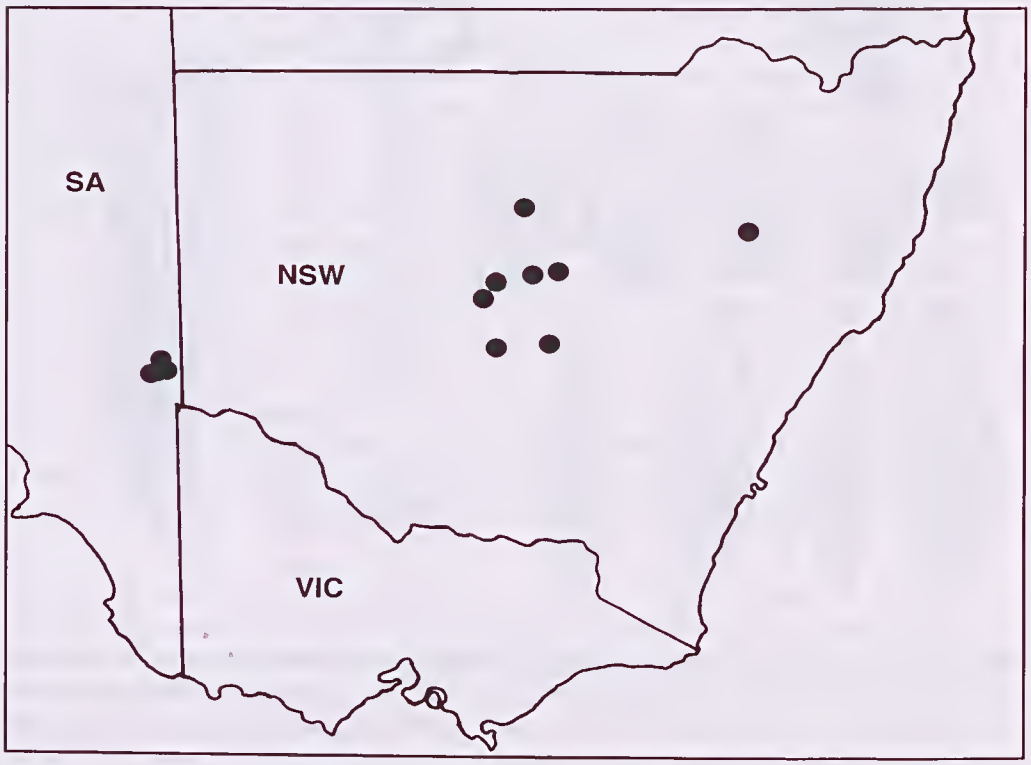

Fig. 2. Distribution of *Cassinia uncata* in south-eastern Australia.

information in a letter from Allan Cunningham, it seems more appropriate to attribute it as *C uncata* A.Cunn. in DC. This being the case, it seems appropriate to designate a Kew Herbarium specimen as lectotype rather than the one in Geneva, although it could be argued that, if Cunningham is both collector (of all material available in 1838) and describer of the species, all of his specimens are probably of equal weight in choice of lectotype.

Conservation considerations: because the name *Cassinia uncata* has been misapplied to so many other taxa, the species has until now been considered widespread, common and secure. However, the investigations reported here show that *C. uncata* is in fact a relatively rare species of very limited distribution. Many collections and collection sites are old ones. It has not been collected from the vicinity of Condobolin since 1888, or Coolabah since 1900. A search at Euabalong West in 2004 failed to find the species where it had been reported in 1978, although it may have been overlooked (the confusingly similar *C. laevis* was present). Virtually all known surviving populations consist of one to very few individuals. For example, the population in Peisley State Forest (*Orchard & Orchard 7229, 7230*) consisted of just two plants, those between Gilgunnia and Nymagee (*Orchard & Orchard 7232*) of a single plant or (*Orchard & Orchard 7231*) of seven plants, and that at Gilgunnia Rest Area (*Orchard & Orchard 7233*) of just four plants. Populations in and near Breeza State Forest are slightly larger, and some seedlings were noted. No information on the size of the South Australian populations is available, but as all are within the Danggali Conservation Park they must be assumed reasonably secure. The species probably survives in other populations in central-west New South Wales, but it is likely that it is nowhere common, and it should be treated as vulnerable.

Acknowledgments

I thank my wife and field companion Theresa for patient and observant hours spent hunting elusive *Cassinia* species in several States. This paper was based in part on examination of specimens borrowed from or consulted in a number of herbaria (AD, BRI, CANB (incl. CBG), HO, K, MEL, NSW). The Directors, staff and curators of these institutions are thanked for their generosity and patience in making this material available (and in some cases for hosting me on visits to their collections). The Director and staff of CANB are thanked also for their support in providing a congenial place to carry out the research. The original research on which this paper is based was supported in part, many years ago, by a research grant from the Australian Biological Resources Study to the Tasmanian Herbarium. I thank Annette Wilson (ABRS) for assistance with scanning of the illustrations.

References

Beadle NCW (1980) *Students flora of north eastern New South Wales*, vol. 4. (University of New England: Armidale)

Beadle NCW, Evans OD & Carolin RC (1972) *Flora of the Sydney region*. (AH & AW Reed: Sydney)

Bentham G (1867) *Flora Australiensis*, vol. 3. (Lovell Reeve & Co.: London)

Candolle AP de (1838) *Prodromus systematis naturalis regni vegetabilis*, vol. 6. (Treutel & Würtz: Paris, Strasbourg & London)

Cooke DA (1986) *Cassinia*. Pp. 1504–1506 in Jessop JP & Toelken HR (eds) *Flora of South Australia*, vol. 3. (South Australian Government Printer: Adelaide)
Cunningham GM, Mulham WE, Milthorpe PL & Leigh JH (1981) *Plants of western New South Wales*. (NSW Government Printing Office: Sydney)
Eichler H (1965) *Supplement to J.M.Black's flora of South Australia*. (Government Printer: Adelaide)
Everett J (1992) *Cassinia*. Pp. 211–216 in Harden GJ (ed) *Flora of New South Wales*, vol. 3. (New South Wales University Press: Kensington)
Jacobs SWL & Pickard J (1981) *Plants of New South Wales*. (National Herbarium of New South Wales: Sydney)
Burbidge NT & Gray M (1970) *Flora of the Australian Capital Territory*. (ANU Press: Canberra)
McMinn WG (1970) *Allan Cunningham botanist and explorer*. (Melbourne University Press: Carlton)
Orchard AE (2004a) A revision of *Cassinia* (Asteraceae: Gnaphalieae) in Australia. I. Introduction and generic and infrageneric considerations. *Australian Systematic Botany* 17: 469–481.
Orchard AE (2004b) A reassessment of the genus *Haeckeria* (Asteraceae: Gnaphaliae), with definition of a new species in *Cassinia*. *Australian Systematic Botany* 17: 447–467.
Orchard AE (2005) (1676) Proposal for the conservation of *Cassinia* R.Br. (1817) *nom. cons.* (*Asteraceae*) against an additional name *Ozothamnus*, or to change its date of publication to *Cassinia* R.Br. (1813), *Taxon* 54 (1): 199–201.
Puttock CF (1999) *Cassinia*. Pp 742–745 in Walsh NG & Entwisle TG (eds) *Flora of Victoria*, vol. 4. (Inkata Press: Melbourne)
Stanley TD (1986) *Cassinia*. Pp 540–541 in Stanley TD & Ross EM (eds) *Flora of south eastern Queensland*, vol. 2. (Queensland Herbarium: Brisbane)
Wakefield NA (1951) Some notes on *Cassinia* with description of a new species. *Victorian Naturalist* 68: 69–70.
Willis JH (1967) Systematic notes on the indigenous Australian flora. *Muelleria* 1: 117–163.
Willis JH (1973) *Handbook to plants in Victoria*, vol. 2. (Melbourne University Press: Carlton)

Manuscript received 28 August 2006, accepted 12 March 2007

Telopea 11(4) 437–450

Ecdeiocoleaceae and Joinvilleaceae, sisters of Poaceae (Poales): evidence from *rbc*L and *mat*K data

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Abstract

Within Poales, the clade (Poaceae, Ecdeiocoleaceae, Joinvilleaceae) has previously received robust support from DNA sequence data from a range of genes. However, the question of which family (or set of families) is the sister group of Poaceae has not been answered with any degree of confidence, to date. Using *Ecdeiocolea monostachya* as the only representative of its family, other researchers have found the clade to resolve (although mostly with low levels of support) as (*Joinvillea* (*Ecdeiocolea*, Poaceae)). We now provide *mat*K and *rbc*L data for *Georgeantha hexandra*, the sole species in the other genus of Ecdeiocoleaceae, in addition to further sampling of other closely related Poales families. Analyses of our data support the alternative topology of (Ecdeiocoleaceae, Joinvilleaceae) as sister to Poaceae and also help to resolve the position of Flagellariaceae. *Flagellaria* groups with (Poaceae, Ecdeiocoleaceae, Joinvilleaceae) in a graminid clade that is sister to the restiid clade (Anarthriaceae, Restionaceae, Centrolepidaceae) in analyses of *mat*K or *mat*K + *rbc*L data. A high rate of base substitution has previously been noted in Poales; branch lengths in Ecdeiocoleaceae are comparable with those in Poaceae.

Introduction

The molecular phylogeny of Poales (APG 2003) has been the subject of much recent interest. Attention has particularly focussed on six plant families (Ecdeiocoleaceae, Joinvilleaceae, Flagellariaceae, Restionaceae, Centrolepidaceae and Anarthriaceae) that, with Poaceae, form the graminoid clade (Kellogg 2000, Bremer 2002) or 'core Poales' clade (Poales sensu stricto) of Barker et al. (2000) and Michelangeli et al. (2003). Of these, Ecdeiocoleaceae is endemic to southwestern Australia and was distinguished from Restionaceae by Cutler and Shaw (1965), largely on the basis of differences in culm anatomy (Cutler 1969). The species of Ecdeiocoleaceae, *Ecdeiocolea monostachya* F. Muell.[1] and *Georgeantha hexandra* B.G. Briggs & L.A.S. Johnson, both occur in semi-arid regions, whereas Joinvilleaceae and Flagellariaceae occur widely in the Old World tropics and Pacific.

[1] Since this paper was submitted, a second species of *Ecdeiocolea* (still unnamed) has been distinguished (Briggs, unpublished). All data reported here for *Ecdeiocolea* refer to *E. monostachya*.

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Various studies have identified Joinvilleaceae as a possible sister group of Poaceae (e.g. Campbell & Kellogg 1987, Chase et al. 1995, Stevenson & Loconte 1995, Kellogg 2000, GPWG 2001) while, until molecular data became available, Ecdeiocoleaceae were mostly regarded as more closely allied to Restionaceae than to Poaceae. Previously Briggs et al. (2000), on the basis of chloroplast DNA data, drew attention to Ecdeiocoleaceae as part of a small clade centred on Poaceae within the graminoid Poales. Subsequently Bremer (2002), using *rbc*L and *atp*B DNA sequence data, identified (Joinvilleaceae, Ecdeiocoleaceae, Poaceae) as a clade (here referred to as the JEP clade, following Hilu 2004). Bremer also concluded that Ecdeiocoleaceae is sister to Poaceae, a position which was also supported by Duvall (2003). Michaelangeli et al. (2003), using morphology with *atp*A and *rbc*L DNA sequence data, similarly placed Ecdeiocoleaceae as sister to Poaceae, noting that this grouping had low jackknife support but that alternative arrangements among the JEP families had even lower values. Hilu (2004) presented a hypothesis of chromosomal evolution in Poaceae, similarly placing Joinvilleaceae as sister to (Ecdeiocoleaceae, Poaceae). In Linder and Rudall's (2005) phylogenetic hypothesis of 'core Poales' the JEP clade (their graminid clade) is sister to a restiid clade. Thus the graminoid Poales (= 'core Poales') consist of the graminid (or JEP) clade and the restiid clade (Anarthriaceae sens. lat., Restionaceae, Centrolepidaceae), together with Flagellariaceae.

That Ecdeiocoleaceae is the single sister of Poaceae was further supported by results from a large *rbc*L data set for monocot taxa (Janssen & Bremer 2004) and a seven-gene data set including nuclear, plastid and mitochondrial sequences (Chase et al. 2006). Givnish et al. (2006), using *ndh*F data, however, placed *Ecdeiocolea* as sister to (*Joinvillea*, Poaceae) but noted that this topology collapsed to a trichotomy in the strict consensus tree. Preliminary maximum parsimony analysis of 17-gene plastid data provides unstable results concerning the sister group of the grasses, for different taxon samplings (JM Saarela & SW Graham, unpubl. data, pers. com.). In most of the studies mentioned, Ecdeiocoleaceae was represented only by *Ecdeiocolea*.

Flagellaria, the sole genus of its family, has been placed either as sister to the rest of the graminid clade (Bremer 2002, Chase 2004, Chase et al. 2006) or as sister to graminids plus restiids (Graham et al. 2006). The placement of *Flagellaria* within Poales has remained somewhat uncertain (Linder & Rudall 2005, Givnish et al. 2006).

Doyle et al. (1992) and Michelangeli et al. (2003) investigated three large inversions in the chloroplast DNA of Poales, and found that the 28 kilobase and 6 kb inversions are synapomorphies of Joinvilleaceae, Ecdeiocoleaceae and Poaceae, while the *trn*T inversion is apparently autapomorphic in Poaceae. These inversions therefore do not help to resolve the trichotomy of the JEP families, but for the record we report additional results from some other Poales taxa.

This study adds to the relevant DNA sequence data, especially by including the *mat*K sequence for *Georgeantha*. To investigate the difference between our conclusions and those of others who used different taxonomic sampling, we also present results from analyses that vary the taxonomic sampling and method of analysis of our data.

Materials and methods

Taxonomic and genomic sampling: this study analysed chloroplast DNA sequence data from *rbc*L and *mat*K of two species in Ecdeiocoleaceae, two in Joinvilleaceae and one of Flagellariaceae. Three samples of *Ecdeiocolea* and three of *Georgeantha* were sequenced, to check that the sequences used in the analysis were representative of each taxon; all have been submitted to GenBank but only one example from each taxon is included in the analyses[2]. Poaceae sampling reflected the clades indicated by the Grass Phylogeny Working Group (GPWG 2001) with *Anomochloa*, *Streptochaeta*, and *Pharus* representing basal clades, *Oryza*, *Melica* and *Triticum* the BEP clade (Bambusoideae, Ehrhartoideae, Pooideae), and *Aristida*, *Arundo*, *Danthonia*, *Zeugites*, *Zea* and *Eragrostis* from the PACCAD clade (Panicoideae, Arundinoideae, Centothecoideae, Chloridoideae, Aristoideae, Danthonioideae). Where sequences were available in GenBank, a representative was chosen from each subfamily recognised in the GPWG classification.

We have incorporated sequences from GenBank, as well as sequence data on *rbc*L that we (Briggs et al. 2000) and others have published previously, and we provide new sequence data for *rbc*L from a further nine taxa, and *mat*K from 15 taxa. Vouchers have been placed in the National Herbarium of New South Wales; particulars of the taxa (including authorities for names), vouchers and GenBank accession numbers are given in Table 1. For three genera of Poaceae (*Eragrostis*, *Melica* and *Aristida*) *rbc*L and *mat*K data were available in GenBank only from different species of the genus; the relevant species for each gene are listed in Table 1. We also experimented with the use of different sets of outgroup taxa.

DNA extraction and sequencing: DNA extraction, PCR conditions and primers used for *rbc*L have been described previously (Briggs et al. 2000). Amplification of *trn*K used two primers described by Johnson and Soltis (1995); the sequences of these are listed in Table 2, along with the internal sequencing primers used. The PCR program used was 95°C for 5 min, then 35 repetitions of (95°C for 30s, 55°C for 30s and 72°C for 2 min) with a final 10 min at 72°C, in a Corbett Research Palm Cycler. The polymerase enzyme used was 'BioTaq' (Bioline, Lukenwalde, Germany). Other details of PCR and subsequent sequencing are as given previously (Briggs et al. 2000). The portion of *rbc*L included consists of 1210 aligned bases, corresponding to positions 83 through 1292 of the gene in the *Oryza sativa* complete chloroplast DNA reference sequence (GenBank accession X15901).

Sequence alignment and analysis: sequences were aligned by CLUSTAL W, with modification by eye, using the program BioEdit (Hall 1999) version 5.0.6. Parsimony analyses used version 4.0b10 of PAUP* (Swofford 2001) for Power PC. The majority rule consensus trees represent the result of 1000 bootstrap replicates, from full heuristic searches with random taxon addition. The sets of sequence data for the regions of chloroplast DNA were analysed separately and in combination, using parsimony and

[2]In *Ecdeiocolea monostachya* the three *rbc*L sequences were identical; for *mat*K two of the sequences were identical but differed from the third in having two separate single-codon insertions. In *Georgeantha hexandra* the *rbc*L and *mat*K sequences each showed a single-nucleotide substitution in one of the samples.

maximum likelihood (ML) criteria. ML analyses (with ML parameters estimated as part of the ML analysis) used either the default options or the TVM+I+G model selected by the Akaike information criterion (AIC) in Modeltest 3.7 (Posada & Crandall 1998). Since our findings for the sister group of Poaceae differ from those found in a number of other studies, and since Ecdeiocoleaceae was represented in those other studies by *Ecdeiocolea* alone, rather than by both genera of the family, we repeated some of the analyses omitting data either from *Ecdeiocolea* or from *Georgeantha*. In Fig. 1 the topology resulting from PAUP* analysis, from the consensus of 1000 bootstrap replicates, analysed using the criterion of maximum parsimony, is combined with relative branch lengths calculated using the DNAPARS program (in PHYLIP version 3.6) for mapping characters onto the topology, a procedure suggested by Felsenstein (2004). The representatives of Restionaceae, Anarthriaceae and Centrolepidaceae were used to root the tree. Percentage bootstrap support values for nodes are shown.

Inversions in the chloroplast genome: the approach of Doyle et al. (1992) and Michelangeli et al. (2003) was followed to determine the presence or absence of the 28 kb inversion previously reported in some Poales. This used primer pairs that span the ends of the inverted region and that are diagnostic for either the inverted or the uninverted sequence. The presence of the inversion was indicated by amplification with primer combinations *rps*14 +*trn*R at the *rps*14 end of the inversion or by G-UCC3' + G-GCC at the *trn*G-UCC end. Absence of the inversion was indicated by amplification with primers *rps*14 + G-GCC and G-UCC3' + *trn*R at the respective positions. Vouchers for the taxa studied are indicated in Table 1.

Results

Figure 1 illustrates our best inference of relationships of the taxa, based on the combined *rbc*L and *mat*K sequence data summarised in Table 3. Since *mat*K provided more parsimony informative characters than *rbc*L, the combined-data tree largely reflects the findings from *mat*K alone. The analyses gave the following results:

(1) The JEP clade is robustly supported with 100% bootstrap support in all parsimony analyses.

(2) All parsimony analyses that included both genera of Ecdeiocoleaceae gave bootstrap values of 95% or higher to the clade (*Ecdeiocolea*, *Georgeantha*).

(3) The topology ((Joinvilleaceae, Ecdeiocoleaceae) Poaceae) is supported when all relevant data from this study are included. When both *Ecdeiocolea* (Ec) and *Georgeantha* (Ge) are included in the analysis, the (J, (Ec,Ge)) clade receives 97% or 98% support (depending on the outgroups used) from *rbc*L + *mat*K data, or 93% support from *mat*K alone. When Ecdeiocoleaceae is represented by *Ecdeiocolea* alone, the (J,Ec) clade receives low or very low support: 70% from *rbc*L + *mat*K data, or 51% or 55% from *mat*K alone.

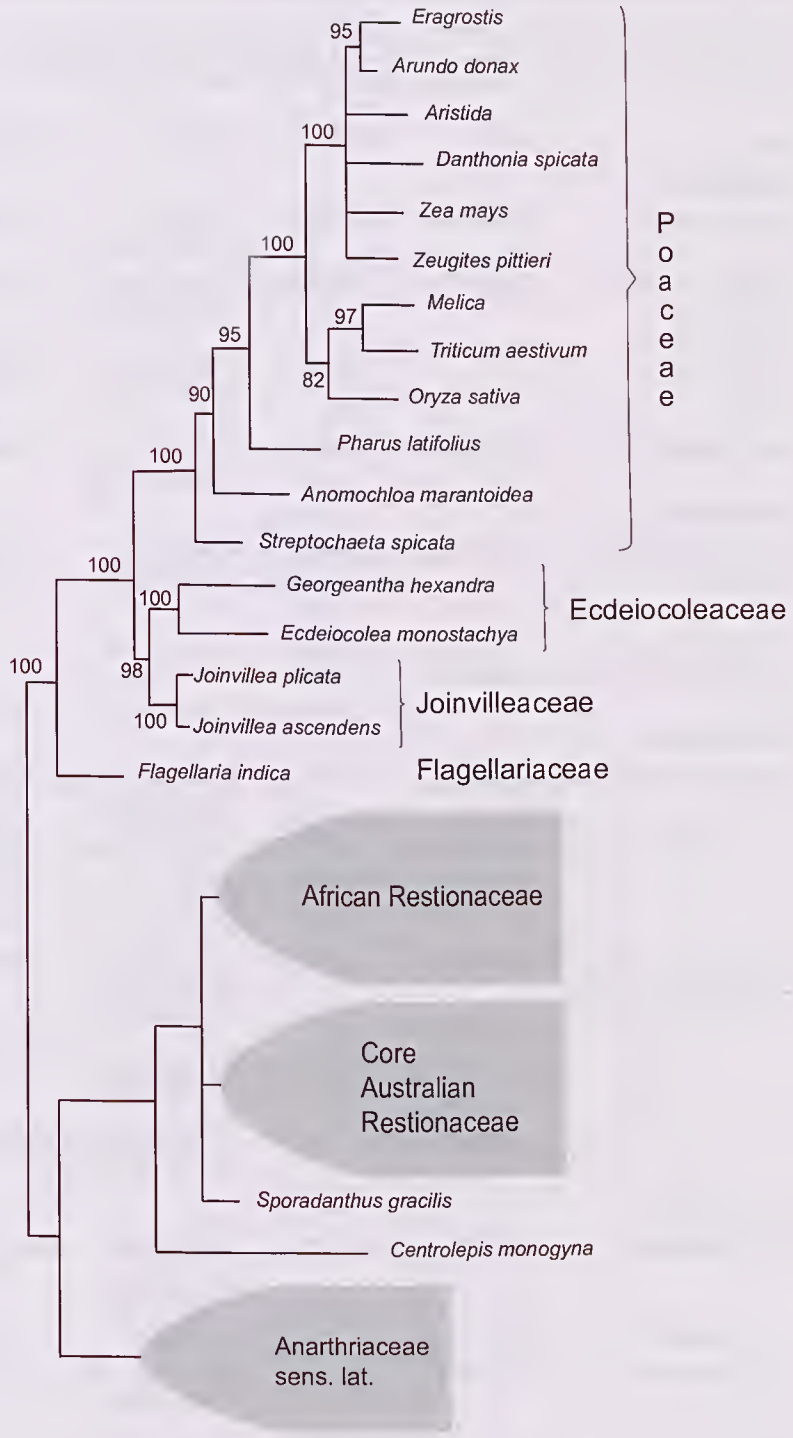

Fig. 1. Consensus tree from analysis of combined *rbc*L and *mat*K sequence data (see text). Percentage bootstrap support values for nodes are shown.

Table 1. Voucher information and GenBank accession numbers for taxa used in this study.

Source and voucher details are given for new sequences; vouchers are placed in the NSW herbarium, except for two collections by Linder et al. deposited at the Institute of Systematic Botany, University of Zurich (Z). Vouchers for study of the 28-kb chloroplast DNA inversion are marked*.

Taxon	*rbc*L	*mat*K	Source	Voucher
Anarthriaceae				
Anarthria prolifera R.Br.	DQ307438	DQ257499	*Meney s.n.*, Jarrahdale, W.A.	NSW415191
Hopkinsia adscendens B.G.Briggs & L.A.S.Johnson	AF148777	DQ257518	*Briggs 9342*, Oldfield River, W.A.	NSW391372*
H. anoectocolea (F.Muell.) D.F.Cutler	–	DQ257519	*Meney 920*, Arrowsmith R., W.A.	NSW364831*
Lyginia barbata R.Br.	AF148787	DQ257523	*Briggs 9321*, N of Cataby, W.A.	NSW391339
Centrolepidaceae				
Centrolepis monogyna (Hook.f.) Benth.	DQ307439	DQ257505	*Briggs 9514*, Lake Dobson, Tas.	NSW494429
Cyperaceae				
Scirpodendron ghaeri Merrill	AB0888323	AB088804		
Ecdeiocoleaceae				
Ecdeiocolea monostachya F.Muell	AF148773	DQ257528	*Meney T20*, S of Eneabba, W.A.	NSW364828*
	DQ307440	DQ257529	*Briggs 9638*, S of Cunderdin, W.A.	NSW716273
	DQ307441	DQ257530	*Perkins*, Watheroo National Park., W.A.	NSW709043
Georgeantha hexandra BG.Briggs & L.A.S.Johnson	DQ307442	DQ257531	*Briggs 9480*, Skipper Road, S of Arrowsmith R., W.A.	NSW 437363
	DQ307443	DQ257532	*Briggs 9653*, NE of Arrowsmith R., W.A.	NSW703380
	DQ307444	DQ257533	*Perkins*, Correy Road, N of Eneabba, W.A.	NSW709054
Flagellariaceae				
Flagellaria indica L.	DQ307445	DQ257515	*Marchant*, cult. Royal Botanic Gardens Sydney	NSW615132*
Joinvilleaceae				
Joinvillea ascendens Brongn. & Gris. subsp. *glabra* Newell	DQ307446	DQ257534	*Briggs 9672*, cult. ex New Caledonia	NSW612727
J. plicata (Hook.f.) T.K.Newell	DQ307447	DQ257535	*Briggs 9673*, cult. ex New Caledonia	NSW612730

Taxon	*rbc*L	*mat*K	Source	Voucher
Poaceae				
Anomochloa marantoidea Brongn.	AF021875	AF164381		
Aristida latifolia Domin	—	AF164413		
Aristida congesta Roem. & Schult. subsp. *barbicollis* (Trin. & Rupr.) de Winter	AJ746283	—		
Arundo donax L.	AJ746284	AF164408		
Danthonia spicata Roem. & Schult.	U31102	AF164409		
Eragrostis capensis Trin.	U31104	—		
E. grandis Hillebr.	—	AF 312342		
Melica altissima L.	—	AF164399		
M. uniflora Retz.	AJ746294			
Oryza sativa L.	X15901	X15901		
Pharus latifolius L.	AY357724	AF164388		
Streptochaeta spicata Schrad. ex Nees	AJ419949	AF164383		
Triticum aestivum L.	NC002762	NC002762		
Zea mays L.	X86563	X86563		
Zeugites pittieri Hack.	AY632374	AF144576		
Restionaceae				
Anthochortus graminifolius (Kunth) H.P.Linder	Hardy pers. comm.	Hardy pers. comm.	Linder et al. 7552	
Baloskion tetraphyllum (Labill.) B.G.Briggs & L.A.S.Johnson subsp. *tetraphyllum*	AF148761	DQ257501	Briggs 9120, Bicheno, Tas.	NSW365050
Calopsis fruticosa (Mast.)	Hardy pers. comm.	Hardy. pers. comm.	Linder et al. 7309	
Chordifex crispatus (R.Br) B.G.Briggs & L.A.S.Johnson	DQ307448	DQ257510	Briggs 9446, E of Wellstead, W.A.	NSW422605
Elegia cuspidata Mast.	AF148774	DQ257512	Romanowski s.n., cultivated	NSW255150
Empodisma minus (Hook.f.) L.A.S.Johnson & D.F.Cutler	DQ307449	—	Briggs 9508, Mt Wellington, Tas.	NSW494674
	—	DQ257513	Briggs 9135, Mt Tim Shea, Tas.	NSW264841
Eurychorda complanata (R.Br.) B.G.Briggs & L.A.S.Johnson	AF148790	DQ257514	Briggs 9136, Mt Tim Shea, Tas.	NSW264949
Lepyrodia glauca (Nees) F.Muell.	AF148785	DQ257521	Pate s.n., Brunswick Junction, W.A.	NSW423726
Platycaulos compressus (Rottb.) H.P.Linder	AY881464	AY881537		
Sporadanthus gracilis (R.Br.) B.G.Briggs & L.A.S.Johnson	DQ307450	DQ257525	Briggs 9263, W of Engadine, N.S.W.	NSW270154
Typhaceae				
Typha latifolia L.	L05464	AB088801		

Table 2. Sequencing Primers for amplication of *trn*K.

Name	Note	Sequence (5' – 3')
*trn*K–3914F (monocot)	a	TGGGTTGCTAACTCAATGG
MBK–F2		TATGAATGGAAAAAACAGCATGTCG
*trn*K–710F	b	GTATCGCACTATGTATCATTTGA
MBK–F3		GTATGGGGGCACCCTATTAGTAAACC
MBK–R2		TCGGCCCAGGTTGGTTTACTAATAGG
MBK–R3		GAAGTTAATCGTAAACAAGAAGATTG
MBKgeoR	c	TCACATTCCGACACATAGGAATTATATAGG
*trn*K–2R	b	AACTAGTCGGATGGAGTAG

(a) from Johnson and Soltis (1995), shortened at 5' end.
(b) from Johnson and Soltis (1995).
(c) designed particularly for *Georgeantha*.

When Ecdeiocoleaceae is represented by only *Georgeantha*, the (J,Ge) clade receives 74% or 79% from *rbc*L + *mat*K data. Using *rbc*L alone, the JEP clade is not resolved or resolves to discordant topologies with very low support.

(4) *Flagellaria* grouped with the JEP families, in a graminid clade that is sister to the restiid clade (Anarthriaceae, Restionaceae, Centrolepidaceae), in analyses of *mat*K or *mat*K + *rbc*L data. The clade (*Flagellaria* (JEP)) was found in ML analyses and received 87% or more support in parsimony analyses. Data from *rbc*L alone was insufficient to resolve the position of Flagellariaceae, which formed a trichotomy with the JEP and restiid clades in such analyses.

(5) When the results of parsimony and ML analyses were compared (Table 3), the interrelationships of the JEP families and of Flagellariaceae were identical under each analysis method, and did not depend on whether ML analyses used the default PAUP* settings (HKY) or the preferred model (TVM+I+G) found by MODELTEST. Including taxa from a range of outgroup families of Poales (Restionaceae, Centrolepidaceae, Anarthriaceae), rather than *Flagellaria* alone, increased support levels but varying the outgroups did not alter the resultant topologies for the critical nodes. Adding further outgroups from Cyperaceae and Typhaceae seemed to introduce more 'noise' as this reduced the support levels but did not alter the resultant topologies.

(6) We found no indels in *mat*K that assisted in resolving the JEP clade. There was a one-codon insertion shared by all members of that clade but absent in the other families. Our data (Table 4) conformed to the findings of Hilu and Alice (1999) who drew attention to variation in the 3′ end of *mat*K in Poaceae. There is a single base deletion in the majority of Poaceae, but *Anomochloa* retains a plesiomorphic condition, as do Joinvilleaceae and Restionaceae. Such a frame-shift indel is also absent from the other families studied, including Ecdeiocoleaceae. A nearby two-codon insertion occurring in the PACC grasses was absent in the other families. Restionaceae, Centrolepidaceae and part of Anarthriaceae (*Anarthria* but not *Hopkinsia* and *Lyginia*) show a one-codon deletion in this area. The codon (CAA) present at this position in *Hopkinsia* and *Lyginia* is not matched in other sequences and, in those two genera, a one-codon insertion may have followed a deletion that was shared by the three families.

Table 3. Results of analyses of *rbc*L and *mat*K data separately and in combination, with variation in outgroups, method of analysis and in representation of Ecdeiocoleaceae.

Outgroup families are represented as follows: Flagellariaceae: ***Flagellaria indica***; Anarthriaceae: ***Anarthria prolifera, Hopkinsia adscendens, Lyginia barbata***; Restionaceae: ***Anthochortus graminifolius, Baloskion tetraphyllum, Calopsis fruticosa, Chordifex crispatus, Elegia cuspidata, Empodisma minus, Eurychorda complanata, Platycaulos compressus, Sporadanthus gracilis***; Cyperaceae: ***Scirpodendron ghaeri***; Typhaceae: ***Typha latifolia***.Taxon abbreviations: Ec = ***Ecdeiocolea***; Ge = ***Georgeantha***; J = ***Joinvillea***, Joinvilleaceae; P = Poaceae; other abbreviations: P = maximum parsimony; ML = maximum likelihood analysis using PAUP default values; ML* = Maximum Likelihood analysis using TVM+I+G model, selected by the Akaike information criterion in MODELTEST 3.7. Clade structure for the JEP clade, bootstrap support (BS) for parsimony analyses, consistency index (CI) and retention index (RI) are given.

Gene	Representation of Ecdeiocoleaceae	Outgroup	Total characters	Analysis	Variable characters		Clades	BS support for relevant node of (J,Ec,Ge,P) clade	CI	RI	BS support for (Ec,Ge) node
					Informative	Uninformative					
*rbc*L	Ec, Ge	Flagellariaceae	1210	P	143	86	P(J(Ec,Ge))	(J(Ec,Ge)) 60%	0.602	0.616	95%
	Ec			P	133	90	P(Ec,J)	(Ec,J) 58%	0.613	0.596	-
	Ge			P	136	88	Ge(J,P)	(J,P) 76%	0.615	0.598	-
*mat*K	Ec, Ge		1672	P	274	311	P(J(Ec,Ge))	79%	0.770	0.739	96%
	Ec			P	255	299	Ec(J,P)	62%	0.781	0.736	-
	Ge			P	253	300	P(J,Ge)	51%	0.781	0.730	-
*rbc*L + *mat*K	Ec, Ge		2882	P	429	395	P(J(Ec,Ge))	(J(Ec,Ge)) 95%	0.711	0.700	100%
	Ec, Ge			P	763	367	P(J(Ec,Ge))	(J(Ec,Ge)) 98%	0.607	0.793	100%
	Ec, Ge			ML			P(J(Ec,Ge))				-
	Ec			P	747	360	P(J,Ec)	(J,Ec) 74%	0.615	0.801	-
	Ge			P	749	366	P(J,Ge)	(J,Ge) 73%	0.617	0.801	-
*rbc*L	Ec,Ge	Flagellariaceae, Anarthriaceae Restionaceae, Centrolepidaceae	1210	P	218	76	P, J,(Ec,Ge)	(J(EG)P) 100%	0.529	0.777	96%
	Ec,Ge			ML	212	77	P(J(Ec,Ge))				-
	Ec			P	214	76	J,Ec,P	(J,Ec,P) 100%	0.533	0.778	-
	Ge			P			Ge(J,P)	(J,P) 70%	0.535	0.778	-
*mat*K	Ec,Ge		1672	P	545	291	P(J(Ec,Ge))	(J(Ec,Ge)) 93%	0.640	0.812	100%
	Ec,Ge			ML			P(J(Ec,Ge))				-
	Ec			P	535	283	P(J,Ec)	(J,Ec) 55%	0.648	0.812	-
	Ge			P	535	290	P(Ge,J)	(Ge,J) 74%	0.651	0.813	-
*rbc*L + *mat*K	Ec, Ge	Flagellariaceae, Anarthriaceae Restionaceae, Centrolepidaceae Cyperaceae Typhaceae	2882	P	187	407	P(J(Ec,Ge))	(J(Ec,Ge)) 97%	0.583	0.767	97%
	Ec, Ge			ML*			P(J(Ec,Ge))				-
	Ec			P	801	407	P(J,Ec)	(J,Ec) 70%	0.590	0.773	-
	Ge			P	805	404	P(J,Ge)	J,Ge) 79%	0.591	0.772	-
*rbc*L	Ec, Ge		1210	P	231	103	P, J(Ec,Ge)	P, J,(Ec,Ge) 100%	0.526	0.759	97%
	Ec			P	226	104	J,Ec,P	(J,Ec,P) 100%	0.533	0.762	-
	Ge			P	228	102	Ge(J,P)	(J,P) 60%	0.531	0.758	-
*mat*K	Ec, Ge		1672	P	586	304	P(J(Ec,Ge))	(J(Ec,Ge))	0.606	0.771	91%
	Ec			P	575	299	P(J,Ec)	(JJ,Ec)	0.614	0.780	-
	Ge			P	578	302	P(J,Ge)	(J,Ge)	0.615	0.779	-

Table 4. Sequence for the 3′ end of *mat*K.

The stop codon is underlined (alignment largely following Hilu and Alice 1999).

Anarthriaceae	
Hopkinsia adscendens	CTGGTGAATCGTCAA———TAA
Lyginia barbata	CTGGTGAATCCTCAA———TAA
Anarthria prolifera	CTGGTGAATCAT————TAA
Centrolepidaceae	
Centrolepis monogyna	CTAGCAAATCTG————TAA
Cyperaceae	
Scirpodendron ghaeri	CTTATTAGTCATTTC————TAA
Ecdeiocoleaceae	
Ecdeiocolea monostachya	CTGGTGAATTATTCT————TAA
Georgeantha hexandra	CTGGTGAATCATTCT————TAA
Flagellariaceae	
Flagellaria indica	CTGGTGAATCATTGG———TAA
Joinvilleaceae	
Joinvillea ascendens	CTGGTGAATCATTCT———TAA
Joinvillea plicata	CTGGTGAATCATTCT———TAA
Poaceae	
Anomochloa marantoidea	CTGGTGAATTACTCT———TAA
Aristida latifolia	CTGGTGAATC-CTCTTACTCTTAATTAA
Arundo donax	CTGGTGAATC-CTCTTATTCTTAATTAA
Danthonia spicata	CTGGTGAATC-CTCTTACTCTTAATTAA
Eragrostis grandis	CTGGTGAATC-CCCTTACTCTTAATTAA
Melica altissima	CTGGTGAACC-CTCT———TAATTAA
Oryza sativa	CTGGTGAATC-CTCT———TAATTAA
Pharus latifolius	CTGGTGAATC-CTGA———TAATTAA
Streptochaeta spicata	CTGGTGAATCATTCT———TAATTAA
Triticum aestivum	CTGGTGAATC-CTCT———TAATTAA
Zea mays	CTGGTGAATC-CTCTTACTCTTAATTAA
Zeugites pittieri	CTGGTAAATC-CTCTTACTTATAATTAA
Restionaceae (African)	
Anthochortus graminifolius	CTGGCGAATCTT————TAA
Calopsis fruticosa	CTGGCGAACCTTTCATTT—TAA
Elegia cuspidata	CTGGCGAATCCT————TAA
Platycaulos compressus	CTGGCGAATCTTTCATTATGGATCATGA*
Restionaceae (Australian)	
Chordifex crispatus	CTGGCAAATCCG————TAA
Baloskion tetraphyllum	CTAGCAAATCTG————TAA
Empodisma minus	CTGGCAAATCTC————TAA
Eurychorda complanata	CTGGCAAATCCG————TAA
Sporadanthus gracilis	CTGGCAAATCTT————TAA
Typhaceae	
Typha latifolia	TTAGTGAACCATTGA———TAA

*there are 29 additional nucleotides in this sequence (not shown); terminating with a TGA stop codon.

Table 5. Presence of 28 kb inversion in the chloroplast genome: results from this study and previous reports on the same genera.

Family	Taxon	28 kb inversion	Previous reports
Anarthriaceae	*Anarthria prolifera*	absent	absent in *A. scabra* (Michelangeli et al. 2003)
	Hopkinsia adscendens	absent	
	Hopkinsia anoectocolea	present	
Ecdeiocoleaceae	*Ecdeiocolea monostachya*	present	present (Michelangeli et al. 2003)
	Georgeantha hexandra	present	
Flagellariaceae	*Flagellaria indica*	absent	absent (Doyle et al. 1992)
Restionaceae	*Lepyrodia glauca*	absent	

(7) The 28-kb inversion in the chloroplast genome was found to be present in three taxa (Table 5), while its absence in three other taxa was confirmed.

Discussion

Rate of nucleotide substitution: previous studies have drawn attention to the unusually high rate of nucleotide substitution, compared with other angiosperms, in the DNA of *rbc*L in Poaceae. Such long branch lengths in other Poales were noted by Bremer (2000) and are evident in the multi-gene analyses of Graham et al. (2006), Chase et al. (2006) and Givnish et al. (2006). Branch lengths in Ecdeiocoleaceae are similarly long, unlike those of Joinvilleaceae (Fig. 1).

Phylogenetic results: there is robust support in all trees for the major clades and relationships previously identified in Poales sens. strict. by Briggs et al. (2000), Bremer (2002), Michelangeli et al. (2003), Chase et al. (2006) and Graham et al. (2006). In particular, strongly supported clades here are (Poaceae, Ecdeiocoleaceae, Joinvilleaceae) and (Restionaceae, Centrolepidaceae). We also find robust support for the monophyly of Ecdeiocoleaceae. The two genera of Ecdeiocoleaceae, each regarded as monotypic until the very recent discovery of a second species of *Ecdeiocolea* (not yet named), show great similarity in vegetative and reproductive structures, including highly distinctive culm anatomy, shapes and textures of floral parts, seed ornamentation and an unusual reproductive biology (i.e. a form of monoecy with multiple switching between the production of female and male flowers along the length of the spike). Differences between *Georgeantha* and *Ecdeiocolea* include the former's trimerous flowers and dehiscent fruits. Michaelangeli et al. (2003) suggested that, if the indehiscent fruit type is homologous in *Ecdeiocolea* and Poaceae, these may be more closely allied than either of them is to *Georgeantha,* whereas Rudall et al. (2005) interpreted the dehiscence of *Georgeantha* fruits as the result of a character reversal. In view of the overall morphological similarity between *Ecdeiocolea* and *Georgeantha*, it is surprising that both *rbc*L and *mat*K show considerable divergence between them. Indeed, from *rbc*L data, an age estimate of more than 55 my BP for their divergence is given by Bremer (2002), and 73 my BP by Janssen and Bremer (2004), comparable to the age of crown Poaceae.

The trees from our *mat*K and our combined data agree with Bremer (2002), Chase (2004) and Chase et al. (2006) in finding Poales sens. strict. to divide into a graminid and a restiid clade, with *Flagellaria* associating with the JEP families to form the graminid clade, while (Anarthriaceae (Restionaceae, Centrolepidaceae)) form the restiid clade. By contrast, the insufficiently resolved *rbc*L tree placed *Flagellaria*, Anarthriaceae and (JEP families + Restionaceae including Centrolepidaceae) at a trichotomy, a position for *Flagellaria* more in agreement with the results from combined data of morphology, *atp*A and *rbc*L (Michelangeli et al. 2003). Graham et al. (2006) and Givnish (2006) found *Flagellaria* to be sister to a clade including both Poaceae and Restionaceae. Data from *rbc*L, *mat*K and *trn*L–F relevant to relationships within the restiid clade will be presented elsewhere.

Presence of 28-kb inversion in chloroplast genome: this inversion has previously been reported (Doyle et al. 1992, Michelangeli et al. 2003) as present in *Ecdeiocolea, Joinvillea* and all Poaceae sampled, but as absent in *Flagellaria* and *Anarthria.* Our findings are in agreement with these earlier reports for Ecdeiocoleaceae and Flagellariaceae.

There have been discordant findings in Restionaceae since these authors reported the inversion as present but Katayama and Ogihara (1996) reported it as absent in the restionaceous genera they studied; our evidence also indicated its absence in *Lepyrodia*. The results for the two species of *Hopkinsia* are discordant and this genus should be investigated further. The strong amplification in *H. anoectocolea*, indicating presence of the inversion, was unexpected since results for *H. adscendens* and *Anarthria* indicated that the inversion was not present.

Conclusion

Determining whether Ecdeiocoleaceae alone or (Ecdeiocoleaceae, Joinvilleaceae) is sister to Poaceae has a parallel in endeavours to determine whether the basal branch of the angiosperms is *Amborella* or (*Amborella*, Nymphaeales). Studies by Zanis et al. (2002) and Leebens-Mack et al. (2005) give a salutary warning against accepting as conclusive a topology with high bootstrap support but limited taxon sampling.

Our study supports the clade (Ecdeiocoleaceae, Joinvilleaceae) as sister to Poaceae. However, others (Chase 2004, Chase et al. 2006, Graham pers. com.) have investigated a wider range of genes in the Poales and found support for Ecdeiocoleaceae alone as the sister group. Adding *Georgeantha* to the sampling of Ecdeiocoleaceae, as in our study, greatly increases support for the ((Joinvilleaceae, Ecdeiocoleaceae) Poaceae) topology.

Acknowledgments

We thank Darren Crayn, Margaret Heslewood, Andrew Perkins, Chris Quinn, Helen Stevenson, John Thomson, and Peter Weston for assistance, helpful discussions or comment on the manuscript. Carolyn Porter and Simon Gilmore contributed to the sequencing studies. Jerrold Davis, Kathy Meney, John Pate, Andrew Perkins, Carolyn Porter and Patricia Meagher assisted with fieldwork or provided plant materials or DNA samples. We thank Mark Chase, Jerrold Davis, Sean Graham, Chris Hardy and Peter Linder for making findings and manuscripts available to us in advance of publication. The helpful comments of a reviewer are also acknowledged.

References

APG (2003) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* 141: 399–436.

Barker NP, Clark LG, Davis JI, Duvall MR, Guala GF, Hsiao C, Kellogg EA, Linder HP, Mason-Gamer R, Mathews S & Spangler R (2000) A phylogeny of the grass family (Poaceae), as inferred from eight character sets. Pp. 3–7 in Jacobs SWL & Everett J (eds) *Grasses: systematics and evolution*. (CSIRO: Melbourne)

Bremer K (2000) Early Cretaceous lineages of monocot flowering plants. *Proceedings of the National Academy of Sciences of the USA* 97: 4707–4711.

Bremer K (2002) Gondwanan evolution of the grass alliance of families (Poales). *Evolution* 56: 1374–1387.

Briggs BG, Marchant AD, Gilmore S, & Porter CL (2000) A molecular phylogeny of Restionaceae and allies. Pp. 661–671 in Wilson KL & Morrison D (eds) *Monocots: systematics and evolution*. (CSIRO: Melbourne)

Campbell CS & Kellogg EA (1987) Sister group relationships of the Poaceae. Pp. 217–224 in Soderstrom TR, Hilu KW, Campbell CS & Barkworth ME (eds) *Grass systematics and evolution*. (Smithsonian Institution Press: Washington)

Chase MW (2004) Monocot relationships: an overview. *American Journal of Botany* 91: 1645–1655.

Chase MW, Fay MF, Devey DS, Maurin O, Rønsted N, Davies TJ, Pillon Y, Petersen G, Seberg O, Tamura MN, Asmussen CB, Hilu K, Borsch T, Davis JI, Stevenson DW, Pires JC, Givnish TJ, Sytsma KJ, McPherson MA, Graham SW & Rai HS (2006) Multi-gene analyses of monocot relationships: a summary. *Monocots: Comparative Biology and Evolution*. Proceedings of 3rd International Conference on Monocotyledons. *Aliso* 22: 63–75.

Chase MW, Stevenson DW, Wilkin P & Rudall PJ (1995) Monocot systematics: a combined analysis. Pp. 685–730 in Rudall PJ, Cribb PJ, Cutler DF & Humphries CJ (eds) *Monocotyledons: systematics and evolution*. (Royal Botanic Gardens: Kew)

Cutler DF (1969) *Anatomy of the Monocotyledons IV. Juncales*. (Oxford University Press: Oxford)

Cutler DF & Shaw HKA (1965) Anarthriaceae and Ecdeiocoleaceae: two new monocotyledonous families, separated from the Restionaceae. *Kew Bulletin* 19: 489–499.

Doyle JJ, Davis JI, Soreng RJ, Garvin D & Anderson MJ (1992) Chloroplast DNA inversions and the origin of the grass family (Poaceae). *Proceedings of the National Academy of Sciences of the USA* 89: 7722–7726.

Duvall MR (2003) Phylogeny of the grasses (Poaceae) revisited. P.23 in Monocots III Abstracts.(Rancho Santa Ana Botanic Garden: California)

Felsenstein J (2004) PHYLIP (Phylogeny Inference Package) version 3.6. Distributed by the author. (Department of Genome Sciences, University of Washington, Seattle: Washington)

GPWG (2001) Phylogeny and subfamilial classification of the grasses (Poaceae). *Annals of the Missouri Botanical Garden* 88: 373–457.

Givnish TJ, Pires JC, Graham SW, McPherson MA, Prince LM, Patterson TB, Rai HS, Roalson EH, Evans TM, Hahn WJ, Millam KC, Meerow AW, Molvray M, Kores PJ, O'Brien HE, Hall JC, Kress WJ & Sytsma KJ (2006) Phylogenetic relationships of monocots based on the highly informative plastid gene *ndh*F: evidence for widespread concerted convergence. *Monocots: Comparative Biology and Evolution*. Proceedings of 3rd International Conference on Monocotyledons. *Aliso* 22: 28–51.

Graham SW, Zgurski JM, McPherson MA, Cherniawsky DM, Saarela JM, Horne EFC, Smith SY, Wong WA, O'Brien HE, Biron VL, Pires JC, Olmstead RG, Chase MW & Rai HS (2006) Robust inference of monocot deep phylogeny using an expanded multigene plastid data set. *Monocots: Comparative Biology and Evolution*. Proceedings of 3rd International Conference on Monocotyledons. *Aliso* 22: 3–21.

Hall TA (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* 41: 95–98.

Hilu KW (2004) Phylogenetics and chromosomal evolution in the Poaceae (grasses). *Australian Journal of Botany* 52: 13–22.

Hilu KW & Alice LA (1999) Evolutionary implications of *mat*K indels in Poaceae. *American Journal of Botany* 86: 1735–1741.

Janssen T & Bremer K (2004) The age of major monocot groups inferred from 800+ *rbc*L sequences. *Botanical Journal of the Linnean Society* 146: 385–398.

Johnson LA & Soltis DE (1995) Phylogenetic inference in Saxifragaceae sensu stricto and *Gilia* (Polemoniaceae) using *mat*K sequences. *Annals of the Missouri Botanical Garden* 82: 149–175.

Katayama H & Ogihara Y (1996) Phylogenetic affinities of the grasses to other monocots as revealed by molecular analysis of chloroplast DNA. *Current Genetics* 29: 572–581.

Kellogg EA (2000) The grasses: a case study in macroevolution. *Annual Review of Ecology and Systematics* 31: 217–238.

Leebens-Mack J, Raubeson LA, Cui L, Kuehl JV, Fourcade MH, Chumley TW, Boore JL, Jansen RK & dePamphilis CW (2005) Identifying the basal angiosperm node in chloroplast genome phylogenies: sampling one's way out of the Felsenstein zone. *Molecular Biology and Evolution* 22: 1948–1957.

Linder HP & Rudall PJ (2005) Evolutionary history of Poales. *Annual Review of Ecology, Evolution, and Systematics* 36: 107–124.

Michelangeli FA, Davis JI & Stevenson DW (2003) Phylogenetic relationships among Poaceae and related families as inferred from morphology, inversions in the plastid genome, and sequence data from the mitochondrial and plastid genomes. *American Journal of Botany* 90: 93–106.

Posada D & Crandall KA (1998) MODELTEST: testing the model of DNA substitution. *Bioinformatics* 14: 817–818.

Rudall PJ, Stuppy W, Cunniff J, Kellogg EA & Briggs BG (2005) Evolution of reproductive structures in grasses (Poaceae) inferred by sister-group comparison with their putative closest living relatives, Ecdeiocoleaceae. *American Journal of Botany* 92: 1432–1443.

Stevenson DW & Loconte H (1995) Cladistic analysis of monocot families. Pp. 543–578 in Rudall PJ, Cribb PJ, Cutler DF & Humphries CJ (eds) *Monocotyledons: systematics and evolution.* (Royal Botanic Gardens: Kew)

Swofford DL (2001) PAUP*: phylogenetic analysis using parsimony (and other methods). Version 4.0b10. (Sinauer, Sunderland: Massachusetts)

Zanis MJ, Soltis DE, Soltis PS, Mathews S & Donoghue M (2002) The root of the angiosperms revisited. *Proceedings of the National Academy of Sciences of the USA* 99: 6848–6853.

Manuscript received 19 July 2006, accepted 20 March 2007

Telopea 11(4) 451–462

New species and new reports in the Australian Graphidaceae

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Abstract

Four new species, ***Anomomorpha roseola, Fissurina praetermissa, Graphis eimeoensis*** and ***Graphis glorioseusis*** are reported from Australia. *Diorygma hololeucum* (Mont.) Kalb, Staiger & Elix, *Graphis atrofusca* Müll.Arg., *Graphis geraensis* Redinger, *Graphis illota* Müll.Arg., *Graphis macella* Kremp., *Graphis maritima* (A.W.Archer) A.W.Archer, *Graphis tenellula* Vain., *Phaeographis epruinosa* (Redinger) Staiger and *Platygramme platyloma* (Müll.Arg.) M. Nakan. & Kashiw. are reported for the first time from Australia. The lichen genus *Anomomorpha* is reported for the first time from Australia.

Introduction

A recent account of the lichen family Graphidaceae in Australia (Archer 2006) listed 127 species , including 8 species in the genus *Diorygma*, 10 species in *Fissurina*, 54 species in *Graphis*, 19 species in *Phaeographis* and 8 species in *Platygramme*. A recent examination of further specimens from BRI and CANB has found additional species, including four new species, viz; *Anomomorpha roseola*, *Fissurina praetermissa*, *Graphis eimeoensis* and *Graphis gloriosensis* together with six *Graphis* species not previously reported from Australia: *Graphis atrofusca* Müll.Arg., *Graphis geraensis* Redinger, *Graphis illota* Müll. Arg., *Graphis macella* Kremp., *Graphis maritima* (A.W.Archer) A.W.Archer and *Graphis tenellula* Vain. The genus *Anomomorpha* Nyl. is reported for the first time in Australia and *Diorygma hololeucum* (Mont.) Kalb, Staiger & Elix, *Phaeographis epruinosa* (Redinger) Staiger and *Platygramme platyloma* (Müll.Arg.) M.Nakan. & Kashiw. are also reported for the first time in Australia.

In the present work chemical constituents were identified by thin layer chromatography (Elix & Ernst-Russell 1993), high performance liquid chromatography (Elix et al. 2003) and by comparison with authentic samples.

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New species

Anomomorpha roseola A.W.Archer & Elix, ***sp. nov.*** Fig. 1

Similis *Anomomorpha sordida* Staiger sed ascosporiis muriformibus et acidum virensicum et neotriconicum continens.

Type: Australia, New South Wales, Styx River State Forest, Softwood Road, 30°32'S, 152°25'E, alt. c. 1500 m, on bark of tree in rainforest, *R.W. Rogers 10063*, 8 Mar 1988; holotype: BRI 687089; isotype: BRI.

Thallus pale fawn to pale olive green, surface smooth and shiny, corticolous; apothecia lirelliform, sessile, scattered, linear to irregularly oval, lips open, margins inrolled, 1–2 mm long, 0.3–0.5 mm wide; exciple uncarbonised; epithecium pink, white pruinose; hymenium 80–120 µm tall, I-ve, inspersed; ascospores 8 per ascus, hyaline, 10–12 µm long, 6 µm wide, initially 4-locular becoming muriform, 4 x 2-locular, I+ weak blue.

Chemistry: (hplc): neotricone (major), virensic acid (submajor), norperistictic acid (minor), norstictic acid (minor), salazinic acid (trace), protocetraric acid (trace).

Specimen examined: New South Wales: Northern Tablelands: Werrikimbe National Park, Beech Plateau, 80 km NW of Port Macquarie, 31°12'S, 152°19'E, alt. 1000 m, on semi-shaded upper *Nothofagus* trunk, *H. Streimann 63984*, 18 Jun 1999 (CANB).

Anomomorpha roseola is characterised by sessile, open lirellae, revealing a white pruinose, pink epithecium, an uncarbonised exciple, small muriform ascospores, an inspersed hymenium and the presence of neotricone and virensic acid. It is distinguished from *A. subtorquens* (Nyl.) Staiger by the larger ascospores (globular, 5–6 µm diam, in *A. subtorquens*) and the presence of virensic acid in addition to neotricone and norstictic acid. *Graphina samoana* Zahlbr. (Zahlbruckner 1908) has ascospores similar in size to those of *A. roseola* but that species lacks an inspersed hymenium ("non oleo" *fide* Zahlbr. *loc. cit.*) and contains norstictic acid as a major compound.

The genus *Anomomorpha* Nyl. (Nylander in Hue 1891) is one of several older genera in the family Graphidaceae which have recently been resurrected and revised (Staiger 2002). It is characterised by an uncarbonised exciple, an inspersed hymenium, small (<15 µm long) ascospores and the presence of norstictic acid ± neotricone. The genus has been reported from the USA (Florida), Colombia, Brazil, Reunion, the Andaman Islands (Staiger 2002) and the Solomon Islands (Archer 2007); the new species described above represents the first report of the genus in Australia and the occurrence of virensic acid in the genus.

The presence of virensic acid as a significant lichen compound is compatible with the biosynthetic pathway to norstictic acid and neotricone. Oxidation of the 6-methyl group in virensic acid to an aldehyde and intramolecular cyclisation gives the corresponding hydroxylactone, norstictic acid, whereas partial oxidation of the 6-methyl group of virensic acid to a hydroxymethyl group followed by lactonisation, and oxidation of the 4-aldehyde group to a carboxylic acid gives neotricone.

Fissurina praetermissa A.W.Archer & Elix, ***sp. nov.*** Fig. 2

Similis *Fissurina dumastii* Fée sed saxicola et ascosporis muriformibus.

Type: Australia, New South Wales, North Coast, Conglomerate State Forest, Waihou Road, near Waihou, 30°06'S, 153°01'E, alt. c. 400 m, on semi-shaded sandstone rock.

A.W. Archer G 187, 19 Apr 1998; holotype: NSW 740892.

Thallus pale olive green, surface smooth and shiny, corticolous; apothecia lirelline, inconspicuous, immersed, initially slit-like, finally opening to reveal a pale fawn epithecium with pale fawn margins, straight or curved, rarely branched, 0.5–1.5 mm long, 0.1–0.2 mm wide; epithecium epruinose; exciple uncarbonised, complete, pale orange-brown; hymenium 120–150 µm tall, not inspersed, I-ve; ascospores 8 per ascus, ellipsoid, hyaline, 12–16 µm long, 5–7 µm wide, 4–6 x 2-locular, I-ve.

Chemistry: no lichen compounds found.

The species is characterised by the inconspicuous, fissurine lirellae, the saxicolous habit, the small, muriform ascospores and the absence of lichen compounds. It is so far known only from the type specimen. The *Fissurina dumastii* group (Staiger 2002) contains 10 species of which five have spores which are 4-locular and thus distinct from *F. praetermissa*. Of the remaining species, four have larger muriform ascospores (15–35 µm long) and the somewhat similar *F. nitidescens* (Nyl.) Nyl. is corticolous and has ascospores reacting I+ violet. The recently described saxicolous *Fissurina* species, *F. saxicola*, from India (Makhija & Adawadkar 2007) has 4-locular ascospores and contains stictic acid; this species is thus distinct from *F. praetermissa*.

Graphis eimeoensis A.W.Archer & Elix, ***sp. nov.*** Fig. 3

Sicut *Graphis tenellula* Vain. sed excipulo integro et ascosporis majoribus.

Type: Australia, Queensland: Eimeo Salt Marsh, 21°02'S, 149°10'E, alt. sea-level, on *Lumnitzera*, *G.N. Stevens s.n.*, 14 Aug 1976; holotype: BRI 689315.

Thallus off-white to pale fawn, surface smooth and dull, corticolous; apothecia lirelline, conspicuous, numerous, crowded, sessile, prominent, simple, straight or slightly curved, terminally acute, with thalline margin to top of the exciple, lips closed, sometimes becoming slightly open to reveal a white pruinose disc, 0.7–2.0 mm long, 0.2–0.3 mm wide; exciple completely carbonised; hymenium inspersed, I-ve; ascospores 8 per ascus, hyaline, elongate ellipsoid, 54–70 µm long, 9–10 µm wide, 14–16-locular.

Chemistry: norstictic acid

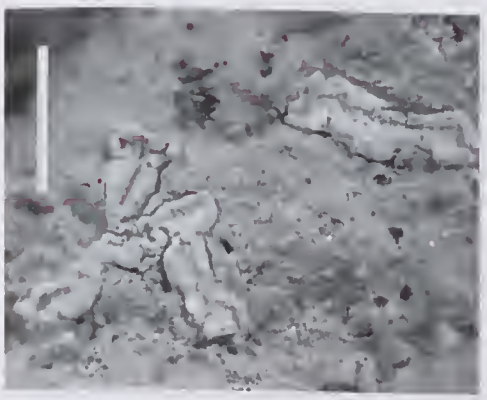

Fig. 1. *Anomomorpha roseola*, holotype. Scale bar = 1 mm

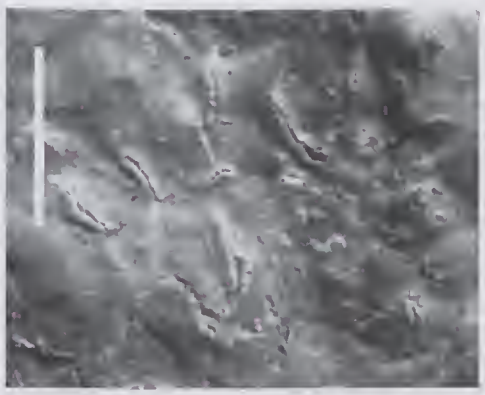

Fig. 2. *Fissurina praetermissa*, holotype. Scale bar = 1 mm

The species is characterised by simple sessile, prominent lirellae, the completely carbonised exciple, inspersed hymenium and the presence of norstictic acid. It resembles the chemically similar *Graphis tenellula* Vain. but that species has smaller ascospores and a laterally carbonised exciple. The Australian species *G. catherinae* A.W.Archer has ascospores of a similar size to *G. eimeoensis* and an inspersed hymenium but lacks lichen compounds. The new species also resembles the chemically similar species *G. lumbriciua* Vain. (Vainio 1899) but that species has larger ascospores, [75-120 µm long], has a striate exciple and the hymenium is not inspersed (Wirth & Hale 1978). The new species is distinguished from *G. centrifuga* Räs. by the smaller ascospores in the latter species.

Graphis eimeoensis is known so far only from the type specimen; it occurs with *Phaeographis ceratoides* Vain. and *Graphis streimannii* A.W.Archer on mangroves at the type location.

Graphis gloriosensis A.W.Archer & Elix, ***sp. nov.*** Fig. 4

Sicut *Graphis rustica* Kremp. sed lirellis furcatis et hymenio insperso.

Type: Australia, Queensland: Highvale, by side of road to Mount Glorious, 27°23'S, 152°49'E, on bark of isolated rainforest tree, *R.W. Rogers 7613*, 8 Jun 1983; holotype BRI 687091.

Thallus off-white to pale fawn, surface smooth and shiny, corticolous; apothecia lirelline, numerous, conspicuous, raised, irregularly branched, 2–4 mm long, 0.1 mm wide, lips closed, with a conspicuous thalline margin; proper exciple completely, or almost completely, carbonised; hymenium inspersed, I-ve; ascospores elongate ellipsoid, hyaline, 50–70(–90) µm long, 10–12 µm wide, 9–14(–16)-locular, I+ blue.

Chemistry: stictic acid.

Specimens examined: New South Wales: North Coast: Cherrytree State Forest, Mallanganee, 30 km WSW of Casino, 28°54'S, 152°43'E, *A.W. Archer G 575*, 13 Nov 2000 (NSW 741791). Northern Tablelands: Dorrigo National Park, track to Crystal Shower Falls, 30°23'S, 152°44'E, alt. c. 700 m, *A.W. Archer G 536*, 2 Nov 2000 (NSW 741792).

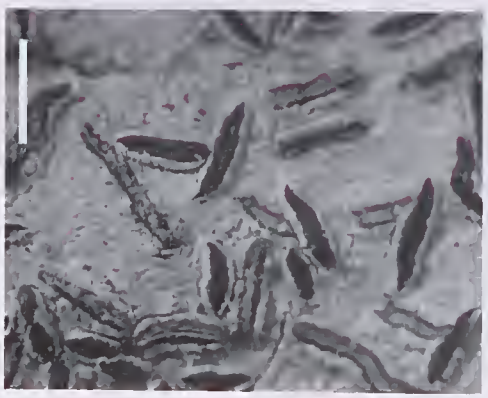

Fig. 3. *Graphis eimeoensis*, holotype. Scale bar = 1 mm

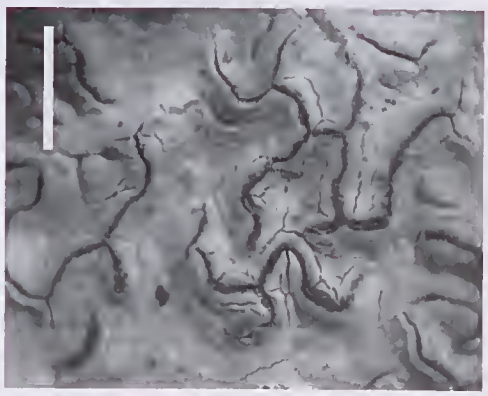

Fig. 4. *Graphis gloriosensis*, holotype. Scale bar = 1 mm

Graphis gloriosensis is characterised by the conspicuous branched lirellae, the completely, or almost completely, carbonised exciple, the inspersed hymenium and the presence of stictic acid. It resembles the chemically similar *Graphis rustica* Kremp. but that species has simple lirellae and a non-inspersed hymenium ["purum" fide Redinger 1936)]. *Graphis gloriosensis* is distinct from the chemically similar *G. crassilabra* Müll. Arg. (Müller 1882) which has a non-inspersed hymenium and immersed lirellae, and from the recently described Indian species *Graphis longissimea* Makhija & Adawadkar (Makhija & Adawadkar 2005) which has a distinctly crenate exciple, an inconspicuous thalline margin, longer lirellae (up to 20 mm long) and a non-inspersed hymenium (U. Makhija *in litt.* 2006). *Graphis superans* Müll.Arg. (Müller 1894) also resembles the new species in lirellae morphology and hymenium inspersion but has larger ascospores and lacks lichen compounds.

The new species is reported from Queensland and New South Wales.

The spelling of the epithet gloriosensis has been chosen deliberately; it is made up of *glorios-*, derived from Mount Glorious, the type location and the Latin suffix *-ensis*, place of origin.

New reports

Diorygma hololeucum (Mont.) Kalb, Staiger & Elix, *Symb. Bot. Ups.* 34: 155 (2004) Fig. 5

= *Graphis hololeuca* Mont., in Junghuhn, *Plantae junghuhnianae* Fasc. IV: 473 (1855)

= *Graphina hololeuca* (Mont.) Müll.Arg., *Flora* 65: 386 (1882)

Type: Java [Indonesia] s. loc., Junghuhn ex herb. Buse; lectotype: L (fide Kalb, Staiger & Elix 2004).

Thallus off-white to pale greenish white, surface smooth and slightly shiny, corticolous; apothecia lirelline, white, conspicuous, numerous, sessile, straight, curved or sinuous, sometimes branched, 2–8 mm long, 0.5–1 mm wide, lips open; proper exciple uncarbonised; disc smooth white pruinose, revealing the black epithecium when abraded; hymenium not inspersed, weak I+ blue at margins; ascospores ellipsoid, hyaline, muriform, 130–160 µm long, 30–36 µm wide, I+ blue.

Chemistry: protocetraric acid

Specimens examined: Queensland: Mossman-Mt Molloy Road, 1 km S of Lions Lookout, 20 km N of Mt Molloy, 16°32'S, 145°23'E, alt. c. 390 m, on canopy of road side tree, *Elix 36875, 36888, 36895, 36898*, 4 Aug 2006 (CANB).

The species is characterised by the conspicuous, white, sessile open lirella and thus differs from the other Australian *Diorygma* species with protocetraric acid, *D. pruinosum*, which has immersed, inconspicuous lirellae.

Diorygma hololeucum has previously been reported from the Philippines, Papua New Guinea, Malaysia and Indonesia (Kalb, Staiger & Elix 2004) and the specimens cited above represent the most southerly locality currently known. The specimens were collected from the canopies of recently felled trees; if tree canopies are the preferred habitat in Australia it may explain why this conspicuous species has not been collected before.

Graphis atrofusca (Müll.Arg.) Stizen., *Ber. Tät. St. Gallisch naturw. Gesellsch.* 1889–1890: 186 (1891) Fig. 6

= *Graphina atrofusca* Müll.Arg., *Flora* 70: 74 (1887)

Type: South Africa, Transvaal, Lydenburg, *Wilms 46* & *70*; syntypes: G.

Thallus off-white to pale greenish white, surface uneven, rough, dull, corticolous; apothecia lirelline, numerous, conspicuous, scattered, simple, straight, curved or sinuous, rarely branched, 1–2(–3) mm long, 0.1–0.25 mm wide, lips open; exciple completely carbonised, thin at the base; disc reddish brown pruinose; hymenium not inspersed, I-ve; ascospores ellipsoid, hyaline, muriform, 30–36 µm long, 16–20 µm wide, 8–10 x 2–5-locular, I+ blue.

Chemistry: no lichen compounds found.

Specimens examined: Queensland: Keppel Sands, Fitzroy Estuary, 23°19'S, 150°47'E, sea-level, on *Excoecaria*, *Rogers 775*, 10 Jun 1975 (BRI 687037); Boydong Island, 11°29'S, 143°02'E, on *Pemphis acidula*, *Youman s.n.*, 17 Jul 1975 (BRI 686972 p.p.).

Graphis atrofusca is characterised by the open lirellae, the completely carbonised exciple, the muriform ascospores and the absence of lichen compounds. It resembles *Graphis semi-aperta* Müll.Arg. but that species has septate ascospores, an inspersed hymenium and contains norstictic acid.

Graphis geraensis Redinger, *Ark. Bot.* 27A(3): 12 (1935) Fig. 7

Type: Brazil, Minas Geraës, São João d'el Rey, *G. Malme 320*, 1 Sep 1892); holotype: S.

Thallus pale olive-green to pale fawn, surface smooth and dull, corticolous; apothecia lirelliform, thin, black, numerous, conspicuous, initially simple, becoming much branched, sessile, lips closed, 1–5 mm long, 0.15–0.25 mm thick; proper exciple completely carbonised; hymenium 90–120 µm tall, not inspersed, I-ve; ascospores 8 per ascus, elongate-ellipsoid, hyaline, 30–40 µm long, 5–8 µm wide, 8–10-locular, I+ve blue.

Chemistry: no lichen compounds found.

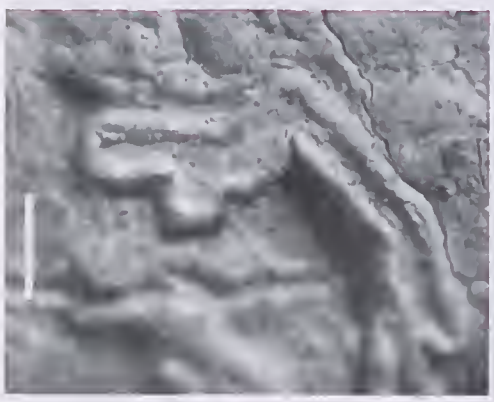

Fig. 5. *Diorygma hololeucum*, Elix 36898. Scale bar = 1 mm

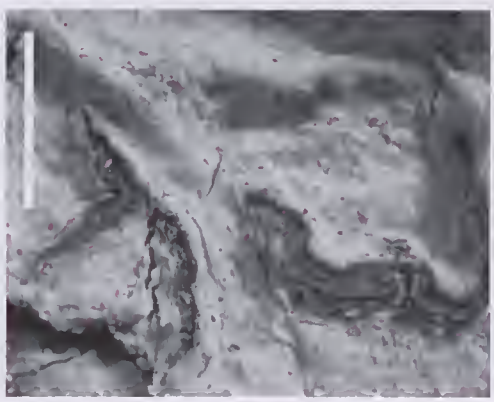

Fig. 6. *Graphis atrofusca*, Rogers 775. Scale bar = 1 mm

Graphis geraensis is characterised by the conspicuous, much branched lirellae, the completely carbonised exciple, the non-inspersed hymenium and the absence of lichen compounds. The ascospores in the holotype were reported to be 4-locular and 15 µm long but these were obviously immature ascospores as the carbonised exciple places the species in *Graphis*, rather than *Fissurina* (Lücking, *in litt.*); in all other respects the Australian specimens agree with the protologue. The species resembles *Graphis intricata* Fée but that species has smaller ascospores (15–26 µm long) and contains norstictic acid.

The species occurs in eastern Australia, in Queensland and New South Wales, and is also found in Brazil.

Specimens examined: Queensland: Numinbah State Forest picnic area, by side of Nerang River, 28°07'S, 153°15'E, c. 20 km W of Burleigh Heads, *Archer G 713*, 23 Oct 2001 (NSW 741796). **New South Wales:** Northern Tablelands: Dorrigo National Park, Wonga Walk, on upper branches of fallen tree, in subtropical rainforest, 30°22'45"S, 152°44'00"E, alt. 700 m, *Archer G 742*, 25 Oct 2005 (NSW 741794); west side of Never Never Creek, c. 9 km N of Bellingen, 30°21'S, 152°54'E, alt. 65 m, *Archer G 822*, 23 Oct 2005 (NSW 741793). Southern Tablelands: Monga National Park, Penance Grove, 28 km SE of Braidwood, 35°35'58"S, 149°54'51"E, alt. 655 m, *Elix 37028*, 1 Mar 2005 (CANB).

Graphis illota Müll.Arg., *Hedwigia* 34: 32 (1895) Fig. 8

Type: Brazil, Santa Catherina Province, *Ule no. 273*; holotype: G: isotype: MICH.

Thallus off-white to pale fawn, surface smooth and dull, corticolous; apothecia lirelline, lirellae conspicuous, scattered, sessile with a complete thalline margin and thin thalline coating on the exposed exciple, sulcate, simple, straight, curved or sinuous, rarely branched, 1–2.5 mm long, 0.3–0.5 mm wide; exciple completely carbonised, lips closed; hymenium not inspersed, I-ve; ascospores elongate ellipsoid, hyaline, (72–)80–100 µm long, 8–12 µm wide, 16–20-locular, I+ blue.

Chemistry: no lichen compounds found.

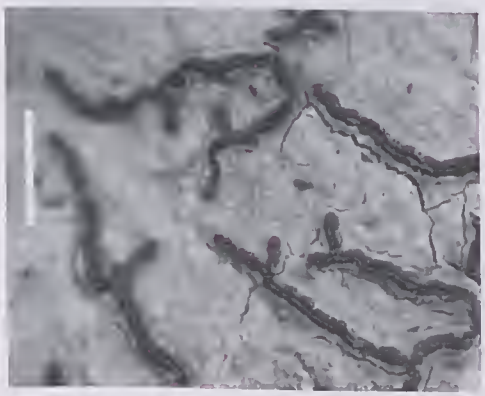

Fig. 7. *Graphis geraensis* , Elix 37028.
Scale bar = 1 mm

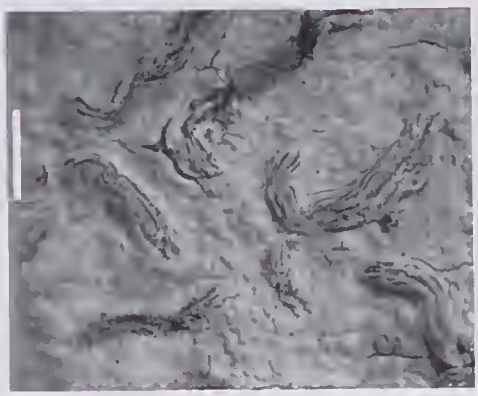

Fig. 8. *Graphis illota*, Rogers 8478.
Scale bar = 1 mm

Specimen examined: Queensland: Mount Glorious, 27°18'S, 152°43'E, alt. c. 600 m, on tree in rainforest, *Rogers 8478*, 31 Jul 1986 (BRI 687028).

The specimen is characterised by conspicuous lirellae with a thalline coating, the large ascospores and the absence of lichen compounds and is tentatively here identified as *Graphis illota* Müll.Arg. The species somewhat resembles *G. flexibilis* Kremp. but both of these taxa are part of a difficult complex and the identification may need to be changed as new information becomes available.

The species also occurs in Brazil and is reported from India (Awasthi 1991).

Graphis macella Kremp., *Flora* 59: 380 (1876) Fig. 9

= *Graphina macella* (Kremp.) Müll.Arg., *Flora* 63: 23 (1880)

Type: Brazil, "ad ramulos Villosiae", *Glaziou 6289b*; holotype: M.

Thallus off-white, surface smooth and somewhat shiny, corticolous; apothecia lirelline, numerous, semi-immersed to sessile, simple, straight, curved or sinuous, rarely branched, striate, the grooves filled with white thalline material, 1–3(–4) mm long, 0.2–0.5 mm wide; exciple laterally, to almost completely, carbonised; hymenium not inspersed, I-ve; ascospores 1 per ascus, ellipsoid, hyaline, muriform, 94–130 µm long, 25–32 µm wide, I+ blue.

Chemistry: no lichen compound found

Specimen examined: Queensland: Mount Glorious, 27°20'S, 152°46'E, on dead rainforest tree, *Stevens 3182*, 9 Apr 1975 (BRI 686890).

The species is characterised by the striate lirellae, the laterally carbonised exciple, the muriform ascospores and the absence of lichen compounds; it is distinguished from the somewhat similar *G. longula* Kremp. by the muriform ascospores.

The species is also reported from Kenya (Staiger 2002).

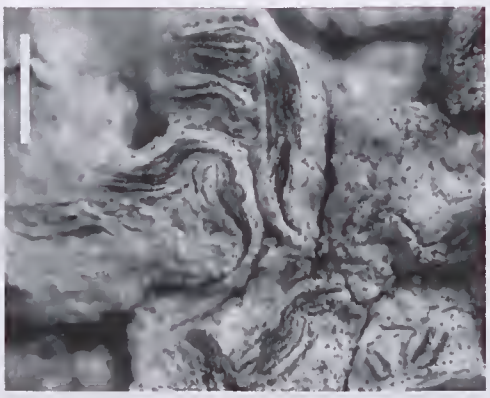

Fig. 9. *Graphis macella*, Stevens 3182. Scale bar = 1 mm

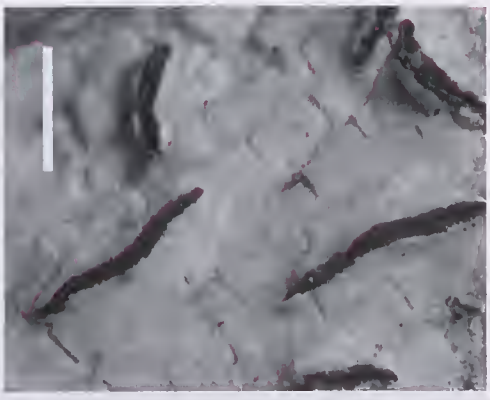

Fig. 10. *Graphis maritima*, BRI 686970. Scale bar = 1 mm

Graphis maritima (A.W.Archer) A.W.Archer, *Systematics and Biodiversity* 5: 16 (2007) Fig. 10

= *Graphina maritima* A.W.Archer, *Mycotaxon* 89: 322 (2004)

Type: Solomon Islands: Makira Province, San Cristobal Island, on trees along the beach, *D.J. Hill 9821*, 15.viii.1965; holotype: BM.

Thallus off-white, thin, surface smooth and dull, corticolous; apothecia lirelline, conspicuous, black, numerous, scattered, simple, straight, curved or sinuous, 1–3 mm long, 0.15–0.3 mm wide, lips closed, with a conspicuous thalline margin, terminally acute; exciple completely carbonised; hymenium not inspersed, I-ve; ascospores narrow-ellipsoid, hyaline, muriform, 8 per ascus, 28–38 µm long, 10–12 µm wide, 8–10 x 2–4-locular, I+ blue.

Chemistry: no compounds found.

Specimen examined: Queensland: Boydong Island, 11°29 S, 143°01 E, on *Salacia chinensis*, *Youman s.n.*, 17 Jul 1985; (BRI 686970).

The species is characterised by the completely carbonised exciple, the muriform ascospores, the non-inspersed hymenium and the absence of lichen compounds. It was previously known only from the Solomon Islands but is now reported from northern Queensland. The species resembles *Graphis platycarpa* Eschw. but is distinguished from that species by the completely carbonised exciple and the smaller ascospores. Superficially, the species resembles *G. geraensis* but differs in the muriform ascospores.

Graphis tenellula Vain., *Ann. Acad. Sci. Fenn.*, Ser. A, (6)7: 160 (1915) Fig. 11

Type: Dominican Republic, La Cumbra, *C. Raunkiaer 490 p.p.*, 9 Apr 1906; holotype: TUR-V 27701.

= *Graphis guimarana* Vain., *Ann. Acad. Sci. Fenn.*, Ser. A,15, 6: 248 (1920). Type: The Philippines, Guimaras, *E.D. Merrill 6716 p.p.*, Mar 1910; holotype: TUR-V 27811.

Thallus off-white to pale fawn, surface smooth and dull, corticolous; apothecia lirelline, numerous, scattered, simple, straight, curved or sinuous, sessile, with a conspicuous thalline margin, 0.5–2 mm long, 0.1–0.2 mm wide, lips closed, rarely slightly open; exciple laterally carbonised, conspicuously open at the base; hymenium inspersed, I-ve; ascospores 8 per ascus, elongate ellipsoid, hyaline, 30–40 µm long, 7–10 µm wide, 8–12-locular, I+ blue.

Chemistry: norstictic acid.

Specimens examined: Northern Territory: Howard Springs, 30 km S of Darwin, *Stevens s.n.*, 14 Jul 1981 (BRI 686941); Nudgee, Nudgee road, on *Poinciana*, *Beasley 4049*, 13 May 1975 (BRI 686906). **Queensland:** Dan Dan Scrub, on Flutter Creek, 24.5 km S of Calliope, 24°12'S, 151°04'E, alt. c. 150 m, in dry rainforest, *Rogers 8092*, 3 Sep 1985 (BRI 687048). **New South Wales**: North Coast: Broken Head, c. 8 km S of Byron Bay, 28°42'S, 153°37'E, alt. c. 100 m, *Archer G 283*, 5 Nov 1998 (NSW 740923); South Ballina, S bank of Richmond River, 28°53'S, 153°31'E, alt. c. 5 m, *Archer G 286*, 2 Nov 1998 (NSW 740922); 6 km NNW of Bellingen, on tree by side of un-named creek at end of Adams Lane, 30°22'20"S, 152°52'E, alt. c. 100 m, *Archer G 743*, 27 Oct 2005 (NSW 740916); Cherrytree State Forest, Mallanganee, 28°54'S, 152°43'E, c. 80 km ENE of Tenterfield, *Archer G 320*, 1 Nov 1998 (NSW 742765).

Graphis tenellula is characterised by the simple lirellae, the laterally carbonised exciple, the inspersed hymenium and the presence of norstictic acid. The species resembles *Graphis librata* C.Knight and the two species were reported as conspecific (Wirth and Hale 1978); however, the ascospores are larger in *G. tenellula* [15–25(–30) µm long in *G. librata*] and the hymenium is not inspersed in the latter species. This is the first report of the species in Australia but it is possible that it has previously been misidentified as *G. librata* C. Knight or *G. desquamescens* (Fée) Zahlbr.

The species occurs in the West Indies, the Philippines and in north and north-eastern Australia and was reported from India, as *G. guinarana* Vain. (Patwardhan & Kulkarni 1976).

Phaeographis epruinosa (Redinger) Staiger, *Bibliotheca Lichenologica* 85: 323 (2002) Fig. 12

= *Phaeographina epruinosa* Redinger, Ark. Bot. 26A(1): 81 (1933

Type: Brazil, Matto Grosso, Coxipó Mirim, *G.A. Malme 3662*, 1 Jun 1984; holotype: S.

Thallus off-white to pale fawn, surface smooth and shiny, corticolous; apothecia lirelline, numerous, conspicuous, sessile, open with a conspicuous thalline margin, straight, curved or sinuous, sometimes irregularly branched, 1–4 mm long, 0.3–0.5 mm wide; proper exciple thin, laterally dark, absent below; epithecium matt black; hymenium 120–140 µm tall, not inspersed, I-ve; ascospores ellipsoid, pale brown, muriform, 30–40 µm long, 10–12 µm wide, 6–8 x 1–3-locular, I+ red brown.

Chemistry: stictic acid (major), constictic acid (minor), cryptostictic acid (trace) and menegazziaic acid (trace).

Specimen examined: Queensland: Tully Gorge, 49 km NW of Tully, 17°45'20"S, 147°37'39"E, alt. 145 m, on trunk of fallen tree, margins of rainforest, *Elix 36979*, *36985*, 28 Jul 2006 (CANB).

Phaeographis epruinosa is characterised by the sessile, open lirellae, the uninspersed hymenium, the small, pale brown, muriform ascospores and the presence of stictic acid. Traces of stictic acid were reported in the holotype by Nakanishi (*in sched.*).

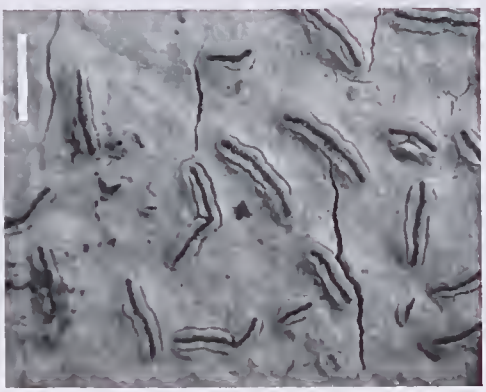

Fig. 11. *Graphis tenellula*, Archer G 283. Scale bar = 1 mm

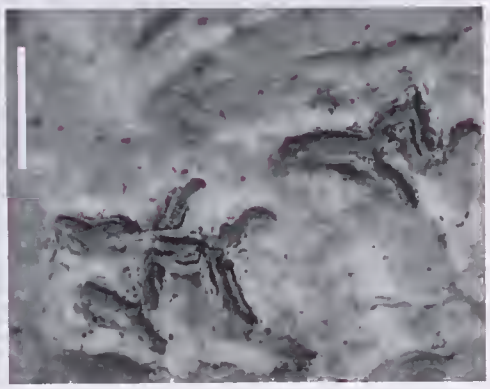

Fig. 12. *Phaeographis epruinosa*, Elix 36979. Scale bar = 1 mm

Two additional species have similar ascospores and contain stictic acid viz: *Phaeographina torquescens* (Nyl.) Redinger (Redinger 1936), and *Phaeographis montiscalvi* (A.W.Archer) A.W.Archer (Archer 2006) but these species are distinguished from *P. epruinosa* by the carbonised exciple and inspersed hymenium, and the closed lirellae respectively.

The species is so far known only from two specimens in Australia and also occurs in Brazil (*fide supra*).

Platygramme platyloma (Müll.Arg.) M.Nakan. & Kashiw., *Bull. Natn. Sci. Mus. Tokyo*, Ser.B 29: 89 (2003) Fig. 13

= *Phaeographina platyloma* Müll.Arg., *Flora* 65: 398 (1882)
= *Phaeographina pudica* (Mont. & Bosch) Zahlbr. var. *platyloma* (Müll.Arg.) Redinger *Rev. Bryol. Lichénol.* 9:97 (1936)

Type: Java [Indonesia], 119a; lectotype: L (fide Nakanishi).

Thallus pale fawn to pale reddish brown, surface smooth and shiny, corticolous; apothecia lirelline, inconspicuous, scattered, sessile, straight, curved or sinuous, sometimes branched, slips slightly open, revealing a black disc, 2–6 mm long, 0.3–0.5 mm wide; exciple conspicuously apically carbonised; hymenium inspersed; ascospores 1 per ascus, elongate ellipsoid, pale brown, muriform, 80–100 µm long, 24–30 µm wide.

Chemistry: no lichen compounds found

Specimen examined: Queensland: Mossman-Mt Molloy Road, 1 km S of Lions Lookout, 20 km N of Mt Molloy, 16°32'S, 145°23'E, alt. c. 390 m, on canopy of road side tree, *Elix 36896*, 4 Aug 2006 (CANB).

The species is characterised by the apically carbonised exciple, the pale brown, muriform ascospores and the absence of lichen compounds. It resembles *P. impudica* (A.W.Archer) A.W.Archer but is distinguished from that species by the smaller ascospores, 80–100 µm long as compared to 135–180 µm long in *P. impudica*. It is distinguished from the somewhat similar species *P. pudica* (Mont. & Bosch) M.Nakan. & Kashiw. by the larger

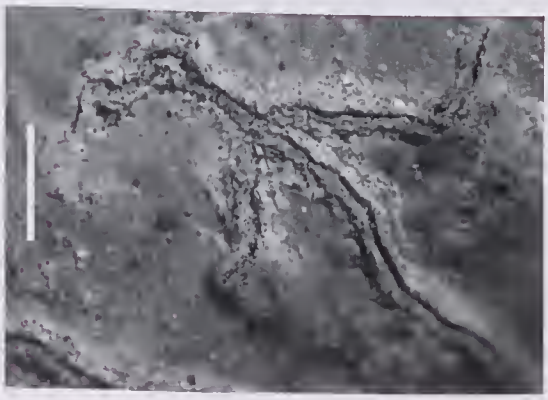

Fig. 13. *Platygramme platyloma*, Elix 36896.
Scale bar = 1 mm

ascospores (160–200 µm long),the concealed carbonised exciple and the presence of echinocarpic acid in that species.

Platygramme platyloma also occurs in Japan and Indonesia.

Acknowledgments

The authors are grateful to Dr. Robert Lücking, Department of Botany, The Field Museum of Natural History, Chicago, for the provision of information on, and illustrations of, several type specimens.

References

Archer AW (2006) The lichen family Graphidaceae in Australia. *Bibliotheca Lichenologica* 94: 1–191.

Archer AW (2007) Key and checklist for the lichen family Graphidaceae (lichenised Ascomycota) in the Solomon Islands. *Systematics and Biodiversity* 5: 9–22.

Awasthi DD (1991) A key to the microlichens of India, Nepal and Sri Lanka. *Bibliotheca Lichenologica* 40: 1–337.

Elix JA & Ernst-Russell KD (1993) *A catalogue of standardised thin layer chromatographic data and biosynthetic relationships for lichen substances*, 2nd. edn. (Australian National University: Canberra)

Elix JA, Kalb K & Wardlaw JH (2003) Neotricone and norperistictic acid, two new depsidones from the lichen genus *Phaeographis*. *Australian Journal of Chemistry* 56: 315–317.

Hue AM (1891) Lichenes exoticos. *Nouvelles Archives du Muséum d'Histoire Naturelle de Paris*, sér. 3, 3: 33–192.

Kalb K, Staiger B & Elix JA (2004) A monograph of the lichen genus *Diorygma*–a first attempt. *Symbolae Botanicae Upsalienses* 34: 133–181.

Makhija U, Kekre S & Patwardhan PG (1992) Materials for a lichen flora of the Andaman Islands: VII—The family Graphidaceae. *Biovigyanam* 18: 12–20.

Makhija U & Adawadkar B (2005) Some new species of *Graphis* (Lichenised Ascomycota) from the Andaman and Nicobar Islands of India. *Mycotaxon* 91: 369–379.

Makhija U & Adawadkar B (2007) Trans-septate species of *Acanthothecis* and *Fissurina* from India. *Lichenologist* 39: 165-185.

Müller J (1882) Lichenologisches Beiträge XVI. *Flora* 65: 499–505.

Müller J (1888) Lichenes Paraguayenses. *Revue Mycologique* 38: 1–32.

Müller J (1894) Lichenes usambarenses. *Botanischer Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie* 20: 238-298.

Patwardhan PG & Kulkarni CR (1976). Some additions to the lichen flora of India IV: *Graphis* and *Graphina* (Family Graphidaceae). *Biovigyanam* 2: 123–1232.

Redinger KM (1936) Die Graphideen der Sunda-Inseln. *Revue Bryologique et Lichénologique* 9: 31–122.

Staiger B (2002) Die Flechtenfamilie Graphidaceae. *Bibliotheca Lichenologica* 85: 1–526.

Vainio EA (1899) Lichenes novi rarioresque. *Hedwigia* 38: 253–259.

Wirth M & Hale ME (1978) Morden-Smithsonian expedition to Dominica: The Lichens (Graphidaceae). *Smithsonian Contributions to Botany* 40: 1–64.

Zahlbruckner A (1908) Die Flechten der Samoa-Inseln, in Rechinger K, Botanische und zoologische Ergebnisse, *Denkschriften der Kaiserlichen Akademie der Wissenschaften Wien, Mathematisch-Naturwissenschaftliche Klasse* 81: 222–287.

Manuscript received 7 December 2006, accepted 24 April 2007

Telopea 11(4) 463–488

The genus *Cycas* (Cycadaceae) in India

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Abstract

The genus *Cycas* is reviewed for India. Eight species are treated, one of them published for the first time (***Cycas indica***). The species are placed within an infrageneric classification previously outlined. Distributions of all taxa are mapped, and a key to species is provided.

Introduction

The genus *Cycas* is the single genus of the family Cycadaceae, itself the basal (sister) lineage of the living cycads (Stevenson 1992). It is also the sole living cycad group occurring in Asia. The only known fossil evidence for this genus is from the Eocene of China and Japan, and this, together with the occurrence of all major lineages in the genus in mainland Asia, supports a long-term presence and probable origin of this genus in that region (Hill 1995). *Cycas* consists of about 100 species, chiefly Indo-Chinese (about 40 species) and Australian (27 species). The genus also occurs in the Malesian region, Japan and India, extending to Micronesia and Polynesia, Madagascar and East Africa. Plants are commonly understorey shrubs in forest, woodland or savanna habitats. The cycad flora of India is relatively sparse in diversity and total numbers in comparison to Indochina and northern Australia, both of which show extensive local radiations. Seven species are known in India.

The present work is the outcome of our separate and combined studies, with a total of 2 field trips during the period 2000–2002. Herbarium collections held by A, B, BM, BO, E, G, K, L, LAE, NY, P and SING have been examined by at least one author. Terminology is as in previous papers in this series (e.g. Hill 1994), as are the generic and specific concepts followed. Conventions in measurements taken and presented in the following descriptions are as follows (see also Hill 2004a, b). Many of the measurements were made on fresh material; in a few instances these measurements are not given in the descriptions because they were omitted in the field.

• The minimum diameter of a single young and actively growing and reproductive stem can be of systematic significance; older stems can be branched or broken several times and maximum diameters are only therefore a measure of age with little systematic significance.

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- The length measured for a leaf is a combined measure of petiole plus lamina.
- Leaflet number is taken as the total number of leaflets on a leaf. Usually a number derived by counting leaflets along one side and doubling the result. Occasionally, numbers are different on each side of a leaf and both sides need to be counted.
- Distance midrib to midrib or top to top is taken as a convention to give a measure of leaflet spacing on the rachis.
- Leaflet to rachis angle is taken as a measure of the angle of insertion of the leaflets i.e. whether leaflets are angled forward as in *C. angulata* or not as in *C. basaltica*. Measured in the plane of one rank of leaflets.
- Leaflet angle to opposing leaflets is taken as a measure of the degree of keeling present in the leaf profile. The angle between the two ranks of leaflets.
- Pinna insertion is described as twisted when insertion is not in a parallel plane to rachis.
- The male sporophyll is typically terminated by a sterile extension. This usually consists of a flat sterile extension lying approximately in the plane of the fertile area, and a sharply differentiated apical spine, usually sharply upturned (see Fig. 3). Measurements for the two distinct parts are usually given separately, but the two may merge together (e.g. *C. nathorstii* below) or the apical spine may be absent (e.g. in some of the Chinese and Vietnamese species, not treated here).
- In the female sporophyll, the length of the lamina is the measurement from the last ovule to the tip, including any apical spine present.

Conservation

Populations of many Asian species appear to have declined, sometimes dramatically, over the past century. However, there is no comparative data to support this impression, and evidence for the decline is largely anecdotal and circumstantial. Several causative factors for this decline can be observed in action today, however, even though quantitative data on the effects are not available. Two principal threats to cycads exist in India at present, habitat loss and selective removal of plants from the wild for trade or utilisation. Some but not all species occur in reserved areas already proclaimed, but enforcement within these areas is sometimes difficult. There is, however, a growing interest in habitat and species conservation within India, and additional reserved areas are being evaluated and declared.

One Indian species (*C. beddomei*) was listed in the now out-of-date (for this region) IUCN 1997 Red Book of Threatened Plants (Walters & Gillet 1998). *C. beddomei* is also the only *Cycas* species on Appendix 1 of CITES, although it is no more endangered than many other species in other countries, and probably less so than some. Species treated below are allocated provisional conservation status codes under the new coding system devised by the IUCN (IUCN 2001). Conservation status of all species is summarised in Table 1.

Table1. Conservation status of cycad species in India

Species	Other countries	1997 Red List	Reserved	IUCN 2003 Status	Pop. Size	Present decline	Range (km²)	Hab. reduct. (%)
C. annakailensis		-	-	DD	?	low	?	?
C. beddomei		E	-	CR	?	low	50	?
C. circinalis		-	y	DD	?	?	500	?
C. indica		-	-	DD	?	?	?	?
C. nathorstii	Sri Lanka	-	-	EN/VU	?	?	?	?
C. pectinata	Vietnam China Thailand	-	y	VU A2c	>10,000	low	?	?
C. spherica		-	-	DD	?	?	?	?
C. zeylanica	Sri Lanka	-	y	VU/EX?	?	?	?	?

Taxonomic history

The first species of *Cycas* described was *C. circinalis* from India (Linnaeus 1753). Of the eight references cited by Linnaeus in the protologue, only two refer to *C. circinalis* as now typified. The other species covered by Linnaeus' description are now known as *C. revoluta* Thunb., separated by Thunberg (1784: 229), and *C. rumphii* Miq., separated by Miquel (1839: 45). The latter is part of a widespread species complex (see Hill 1994), all species of which have been subsequently treated as part of *C. circinalis* at some time or other.

Next to be described was *C. pectinata* (Hamilton 1826), followed soon by *C. spherica* (Roxburgh 1832), although Roxburgh was under a considerable misapprehension concerning the entities he was describing (de Laubenfels & Adema 1998). *C. beddomei* was recognised half a century later (Thiselton-Dyer 1881) and *C. nathorstii* another half century after (Schuster 1932).

The account by de Laubenfels and Adema (1998) records four species from India, *C. circinalis*, *C. beddomei*, *C. spherica* and *C. pectinata*. *C. nathorstii* is included in the synonymy of *C. circinalis* and *C. spherica*, and their interpretation of *C. thouarsii* Gaudich. ex R. Br. includes material treated below under *C. zeylanica*. Singh added *C. annakailensis* in 2006.

Taxonomic treatment

CYCAS L., Sp. Pl.: 1188 (1753).

Lectotype: *C. circinalis* L.; designated by Stevenson in Jarvis et al. (1993).

Dioecious palm-like shrubs with aerial or subterranean, pachycaul, cylindrical stems clad with persistent leaf-bases. Leaves loosely pubescent when young, pinnate, spirally arranged, produced in seasonal growth flushes interspersed with cataphylls, lower leaflets often reduced to spines. Longitudinal ptyxis erect or rarely reflexed, horizontal ptyxis circinate. Leaflets with a single thick midrib and no lateral veins; stomata confined to abaxial surface in most species; individual ptyxis involute. Trichomes transparent, branched or simple. Leaves with vascular traces girdling stems, girdling

traces not present in cataphylls or megasporophlls. Microsporophylls aggregated into determinate cones and bearing numerous microsporangia (pollen-sacs) on abaxial surfaces, with a simple sterile apex, which is often produced into an upturned spine; microsporangia opening by slits; pollen cymbiform, monosulcate. Megasporophylls spirally arranged in an indeterminate terminal rosette with the central axis continuing vegetative growth. Ovules two to many (rarely one), marginally inserted on the stipe and directed obliquely outwards (`ascending'); sporophyll apically dilated into a pinnatifid, pectinate, toothed or entire lamina. Seeds with a yellow, orange or brown fleshy outer sarcotesta, and with or without spongy tissue beneath the inner woody sclerotesta. Endosperm haploid, derived from the female gametophyte. Embryo straight; with 2 cotyledons that are usually united at the tips and a very long, spirally twisted suspensor; seeds platyspermic; germination cryptocotylar.

Four sections have been recognised (Hill 1995), although there has been disagreement on subgeneric division (Wang 1996; de Laubenfels 1998), and, in the light of improved understanding of the genus, none of the proposed systems would appear entirely adequate (Hill 1998; 2004a, b). Two clear groups, regarded below a sections, occur naturally in India, and a third is represented by one widely cultivated species.

Key to sections

1 Ovules tomentose ..... Section *Asiorientales*

1* Ovules glabrous

2 Megasporophyll pectinate..... Section *Indosinenses*

2* Megasporophyll entire or dentate, not deeply pectinate ..... Section *Cycas*

Key to species

1 Ovules and seeds tomentose; leaflet margins strongly recurved ..... #*C. revoluta*

1 Ovules and seeds glabrous; leaflet margins not strongly recurved

2 Sarcotesta with a fibrous layer

3 Megasporophyll apex about as broad as long, lateral teeth more than 10 mm long.....
..... 1. *C. pectinata*

3*Lateral teeth of megasporophyll less than 6 mm long ..... 2. *C. beddomei*

2*Sarcotesta lacking a fibrous layer

4 Spongy endotesta absent

5 Apical spine of megasporophyll not distinctly different from lateral spines, 1–3 mm long .
..... 7. *C. indica*

5* Apical spine of megasporophyll distinctly different from lateral spines, more than 3 mm .
long

6 Lateral teeth less than 5 mm long

7 New growth bluish.....3. *C. circinalis*

7*New growth bright green .....6. *C. nathorstii*

6* Lateral teeth 5–10 mm long

8 Microsporophyll 28–43 mm long; leaves with 55–130 leaflets..... 4. *C. spherica*

8*Microsporophyll 63–83 mm long; leaves with 200–240 leaflets..... 5. *C. annakailensis*

4*Spongy endotesta within the sclerotesta ..... 8. *C. zeylanica*

This species, native to Japan and China and belonging to Section Asiorientales, is widely cultivated throughout Asia. It is not discussed any further in this treatment.

Cycas section Indosinenses Schuster, Pflanzenr. 99: 65 (1932). Type: *C. siamensis* Miq., lecto, fide Hill and Yang (1998). This is one of only two species included in this section by Schuster, and the single species remaining when the other species (*C. micholitzii*) is removed to section *Stangerioides*, as was done by Smitinand (1971).

Section *Indosinenses* is defined by the combination of glabrous ovules, a deeply pectinate megasporophyll lamina, and the presence of a layer of fibrous tissue within the sarcotesta. It is a taxonomically complex group, ranging from Himalayan India east to Vietnam and southern China and south to northern peninsular Malaysia, with a radiation of species in Thailand (Hill & Yang 1998). Sectional circumscription herein follows Wang (1996). One species occurs in India (Fig. 1).

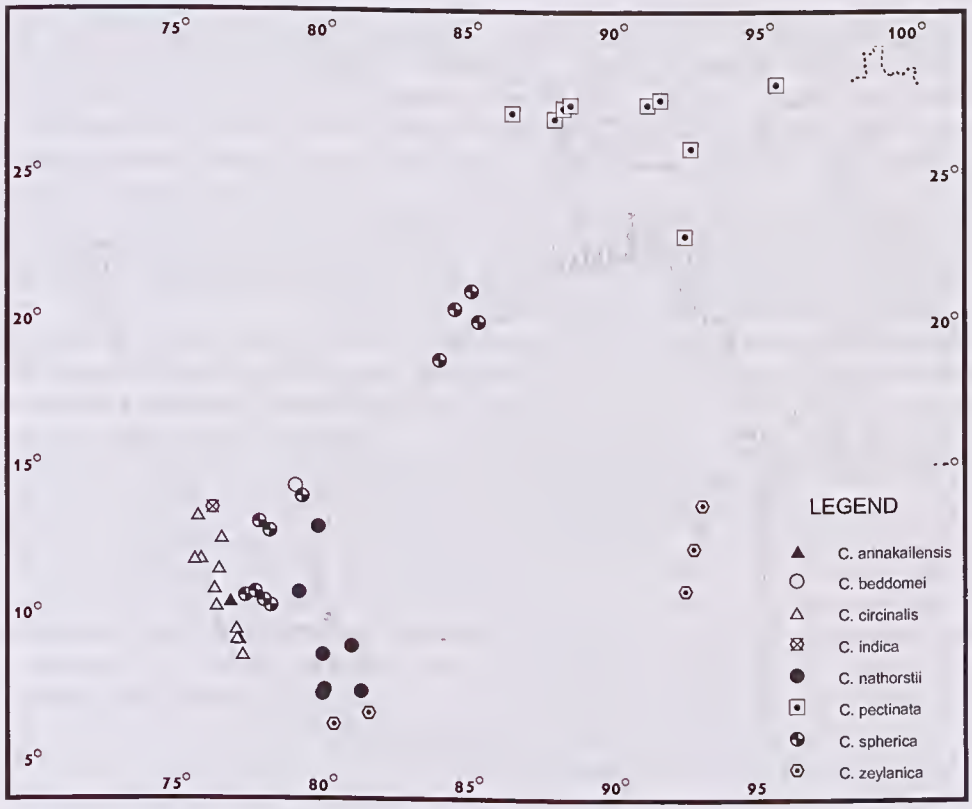

Fig. 1. Distribution of the genus *Cycas* in India.

1. *Cycas pectinata* Buch.-Ham., Mem. Wern. Nat. Hist. Soc. 5(2): 322–323 (1826). *Cycas circinalis* subsp. *vera* var. *pectinata* (Griff.) Schuster, Pflanzenr. 99: 68 (1932).

Type: India, E. Bengal, Chittagong, *J.D. Hooker & Thompson 6*, 1855 (neo K!, isoneo P!). This specimen was designated the lectotype by de Laubenfels and Adema (1998), but this cannot be maintained since the specimen was collected after the species was published. The same specimen has been designated the neotype (fide Hill et al. 2004).

Cycas pectinata Griff., Not. Pl. Asiat. 4: 10 (1854); Ic. Pl. Asiat. 4: Plate 360, fig. 3 (1854); *nom. illegit.*, later homonym of *C. pectinata* Buch.-Ham. (Mem. Wern. Nat. Hist. Soc. 5(2): 322. 1826). **Type:** Icones Plantarum Asiatarum 4: Plate 360, fig. 3. (1854).

Cycas jenkinsiana Griff., Not. pl. Asiat. 4: 9–10, Plates 360, fig. 1–2 and 362, fig. 1 (1854). **Type:** India, Assam, *Jenkins s.n.* (holo K!; iso BM!, L!).

Literature: Kurz (1877), Leandri (1931), Schuster (1932), Ho & Duong (1960), Raizada & Sahni (1960), Suvatabandhu (1961), Smitinand (1971), Grierson & Long (1983), Wang (1996), Tang et al. (1997), Chen and Stevenson (1999), Hill & Yang (1998).

Illustrations: Smitinand (1971), Cheng, Fu & Cheng (1975), Grierson & Long (1983), Wang (1996), Tang et al. (1997), Hill & Yang (1998).

Etymology: Latin *pectina*, a comb, in reference to the long, comb-like teeth of the megasporophylls.

Vernacular: Assam - thaljimura, Burmese - môndaing, Chinese - *bi-chi su-tie* (cycad with comb - like megasporophylls), *feng-wei-jiao* (Phoenix-tail grass or palm), *feng-huang-dan*, Khasi - *dieng-sia-goda*, Nepalese - *thakal, thaljimura*, Thai - *boka, plong, prong khao, prong pa* (forest or field cycad) (Chen et al. 1995, Hill & Vatcharakorn 1998, Pant 1962, Pant et al. 1994, Smitinand 1972, Walters & Yang 1994, Bonta & Osborne 2005).

Stems arborescent, to 1–12 m tall, 14–20 cm diam., (with 30–40 leaves in crown); growing in soil or humus; base not strongly swollen; bark thin and smooth, cataphylls and leaf bases not persistent. *Leaves* deep green to grey-green, semiglossy, 150–240 cm long, flat (not keeled) in section (opposing leaflets inserted at 170–180° on rachis), with 180–312 leaflets, with white tomentum shedding as leaf expands, rachis consistently terminated by a spine 1–46 mm long. Petiole 30–80 cm long (25–50% of total leaf), glabrous, spinescent for 30–80% of length. *Basal leaflets* not gradually reducing to spines, 50–160 mm long. *Median leaflets* simple, strongly discolorous, 200–315 mm long, 7.5–10.5 mm wide, inserted at 45–60° to rachis, decurrent for 4–8 mm, narrowed to 2.5–4 mm at base (to 35–45% of maximum width), 8–13 mm apart on rachis, section flat, margins slightly recurved; apex acute, sometimes spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, pilose, 70–90 mm long. *Pollen cones* ovoid, yellow or green, 30–55 cm long, 16–22 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, 43–60 mm long, 19–24 mm wide, fertile zone 35–57 mm long, sterile apex 3–8 mm long; apical spine prominent, sharply upturned, 17–32 mm long. *Seed cones* closed at pollination, closed as seed set. *Megasporophylls* 22–30 cm long, grey-tomentose, tomentum shedding on older megasporophylls; ovules 2–4, glabrous; lamina orbicular, 110–180 mm long, 100–130 mm wide, deeply pectinate, with 40–50 soft lateral spines 26–75 mm long, 2–3 mm wide; apical spine distinct from lateral spines, 35–75 mm long, 5–12 mm wide at base. *Seeds* flattened-ovoid, 42–45 mm long, 33–45 mm wide; sarcotesta yellow, (not pruinose, 4–7 mm thick), fibrous layer present; sclerotesta smooth; spongy layer absent.

Historical notes: *Cycas pectinata* was the fourth species of *Cycas* to be named, described in 1826 by Scottish surgeon and botanist Francis Buchanan-Hamilton (1762–1829), who worked as a surgeon in the Bengal medical service (1795–1815) and was superintendent of the Botanical Garden Calcutta (1814–1815). No type was cited, but reference was made to occurrence in "the hills which bound Bengal to the east", and the description cited "Habitat in Camrupae orientalis sylvis". *C. angulata* R.Br. and *Olus calappoides* of Rumphius (*C. rumphii* Miq.) were cited (erroneously) in synonymy (Hamilton 1826). Zhou et al. (1990) regarded Hamilton's publication as illegitimate because *C. angulata* was cited as a synonym. The latter was cited, but with a question mark, indicating that the author was unsure of the placement of *C. angulata*. This does not invalidate Hamilton's publication (see McNeill et al. 2006, Art. 52.2, note 1, example 9). The primary set of Hamilton's Bengal collections eventually went to Wallich and thence to Kew (K-W). A second set went to E. Neither set includes a specimen that could be regarded as the type of *C. pectinata*.

The name has been attributed to Griffith (Griffith 1854a, b), although he did not actually add his name to the binomial when describing it (Griffith's practice apparently was to add his name to new binomials, and place no name on existing or previously published binomials).

Distinguishing features: the very large, ovoid male cones with long, narrow microsporophylls, those with long apical spines, readily distinguish this species from others in the *C. pectinata* group. The thin, smooth bark also distinguishes this species from related taxa, although this feature is shared with *C. clivicola* K.D.Hill and *C. elongata* (Leandri) D.Yue Wang.

Distribution and habitat: common and widespread in forest on hills of the south-eastern Himalayas, mostly above about 500 m altitude (Fig. 1). This species occurs in medium to tall forest on deep, often clay-rich and more fertile soils, usually as part of the general shrub under storey at medium to higher elevations in generally moist conditions. in moderate to deep shade. Although often found on soil overlaying limestone substrates, it is by no means restricted to these, and also occurs on granites and metasediments.

C. pectinata is abundant in the hill forests of north-eastern India, and has also been collected from Nepal and Bhutan. It extends into Yunnan Province in southern China, and east into northern Thailand, Laos and Vietnam.

Conservation status: an abundant and widespread species. Although its habitat is continually being reduced, large populations remain, and it is not under any immediate threat of extinction. IUCN status VU A2c (Donaldson 2003) (on the basis of the continuing population decline, although the very large populations remaining indicate that the short-term threat of extinction is low).

Selected specimens: INDIA: Gowatty, *Clark 43243*, 29 Mar 1886 (K); Satte Bhaia Jhai, Darij Serai, *Gamble 2675A*, Jan 1875 (K); Rammagar Hills, *Haines 3983*, Nov 1916 (K); Great Rungeet Valley, Sikkim, *Hooker s.n.*, 1848 (K); Khasia, *Hooker & Thompson*, 16 Jul 1850 (K); Laki, Lakhei County, Lushai Hills, Assam, *Parry 100*, Feb 1927 (K); Koongi Valley, Manipur, *Watt 6796*, 27 Apr 1882 (K). **BANGLADESH:** Chittagong, *Hooker & Thompson Herb. Ind. Or* (BM, K, L); Satakoina, Chittagong, *Hooker & Thompson 595* , 11 Jan 1857 (K). **BHUTAN:** E bank of Dangme Chu, between Cha Zam and Duksun, N of Tashigang, *Grierson & Long 2357*, 29 Jun 1979 (K ex E). **BURMA:** Shan States, *Aplin s.n.*, Nov–Dec 1887 (K); Mundat, *Kingdon Ward 22308*, 18 May 1956 (K); Rangoon, *Meebold 8166*, Jan 1908 (K). **CHINA:** Yunnan, *Henry 13637* (K, NY); Meng Yuan district, Meng La Natural Reserve, *Lindstrom s.n.*, 1994 (no voucher).

NEPAL: Mechizou Jhapa district, *Nicolson 3078*, 31 Mar 1967 (BM); Ganjbari (26 45'N 87 58'E), *Stainton 5733*, 1 Apr 1967 (BM); Udaipur Ganhi (26 56'N 86 31'E), *Stainton 6638*, 3 Nov 1969 (BM). **THAILAND: Chaiyaphum**: near Chulaphorn Dam, *Larsen, Supee, Larsen, Nielsen & Santisuk 31432*, 5 Aug 1972 (BKF). **Chiang Mai:** Doi Pha Hom Pok, Fang, *Kerr 5218*, 3 Apr 1921 (BM, K). **Kanchanaburi:** Ban Huay Sue, E of Thong Pha Phum, *Hill 4645*, 02 May 1994 (NSW, BKF, K, L, PE). **Loei:** Phu Paek, *van Beusekom & Phengklai 3027*, 14 Jan 1970 (L ex BKF). **Mae Hong Son:** Ban Mok Jum Prak, *Hill 4638*, 26 Apr 1994 (NSW). **Phetchabun:** N of Chai Badun, *Abbe, Abbe & Smitinand 9361 B*, 2 Jan 1960 (BKF). **Phrae:** Mae Kating, *Williams & Smitinand 17133* (BKF). **Sukhothai:** Khao Luang, *Kerr 5944*, 4 May 1922 (BM, K). **VIETNAM: Gia Lai:** Kbang (14°04'N 108°40'E), 30 Oct 1994, *Yang 532, Ban & Lindstrom* (HN); Dalat, 5 Nov 1994, *Yang 542, 543, Ban & Lindstrom* (HN). **Kon Tum:** between Dak Poko and Dak Mek rivers, 1000 m alt, 28 Mar 1995, *US Nat. Geog. Soc. Exped. VH 962, 963* (HN); **Quang Ngai:** Duc Pho, pho Khanh, 25 Jan 2000, *Hiep 4162, 4163, 4164 & Hill* (HN, NSW).

Cycas section *Cycas*

Section *Lemuricae* Schuster, Pflanzenr. 99: 65 (1932), nom. illegit.

Section *Cycas* is defined by the combination of glabrous ovules and a non-pectinate megasporophyll lamina. Three subsections are recognised, circumscription following Hill (1995), with two occurring in India. The full range of the section is from India and southern Indochina south to Australia, and from East Africa east to Tonga.

Key to the Subsections

1 Seeds with a spongy layer inside the sclerotesta ..... Subsection *Rumphiae*

1* Seeds lacking a spongy layer ..... Subsection *Cycas*, Subsection *Endemicae*

(Australia and New Guinea only, not discussed further)

Cycas subsection *Cycas*

This subsection of about 10 species is defined by the absence of a spongy endotesta, and the long megasporophyll with a narrow lamina. It ranges from India and Sri Lanka to Luzon, south and east to New Guinea. Most representatives are plants of closed forests, usually on ridges away from the coast. Six species occur in India.

2. *Cycas beddomei* Dyer, Trans. Linn. Soc. London., Bot. (ser. 2) 5: 85, pl. 17 (1881). *Cycas circinalis* subsp. *vera* var. *beddomei* (Dyer) Schust., Pflanzenr. 99: 67 (1932).

Type: India: Cuddapah Hills, *H.H. Yarde s.n.*, Aug. 1882 (syn K!, 3 sheets; isosyn BM!).

Literature: Raizada & Sahni (1960).

Illustrations: Thiselton-Dyer (1881), Warburg (1900).

Etymology: honouring Colonel Richard Henry Beddome (1830–1911), a director of the Lal Bagh, or government gardens, at Bangalore and author of the `Foresters manual of botany for southern India'.

Vernacular: telugu - *per ita*, madhana - *kamakshi* (lit. lust-eyed one, presumably ref. to aphrodisiac properties), unidentified lang. - *konda itha* (Fischer 1928, Schuster 1932, Raizada & Sahni 196, Whitelock 2002, Bonta & Osborne 2005).

Stems arborescent, to 2 m high, 12–23 cm diam., often suckering at the base; usually growing in soil or humus; base not strongly swollen; bark thick, corky, cataphylls and leaf bases persistent. *Leaves* grey-green, dull, c. 90 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis) with brown tomentum shedding as leaf expands. Petiole c. 15 cm long 20–30% of total leaf), glabrous, spinescent. *Basal leaflets* not gradually reducing to spines, *Median leaflets* simple, strongly discolorous, 100–175 mm long, 2–4 mm wide, inserted at 50–60° to rachis, narrowed to 1.5–2.5 mm at base (to 60–75% of maximum width), 4–6 mm apart on rachis; section slightly keeled; margins revolute; apex acute or aristate, spinescent; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, thinly sericeous or lacking tomentum, 50–70 mm long. *Pollen cones* narrowly ovoid, orange, c. 30 cm long, c. 7.5 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, c. 35mm long, c. 15 mm wide, fertile zone c. 30 mm long, sterile apex c. 5 mm long, merging with spine; apical spine prominent, gradually raised, c. 30 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 15–20 cm long, persistently brown-tomentose; ovules 2, glabrous; lamina lanceolate, 65–75 mm long, 20–25 mm wide, regularly dentate with 22–32 pungent lateral spines 5–9 mm long, 1 mm wide; apical spine distinct from lateral spines, 11–15 mm long , 2–3 mm wide at base. *Seeds* flattened-ovoid, 34–38 mm long, 30–34 mm wide; sarcotesta yellow, fibrous layer present; sclerotesta smooth; spongy endotesta absent.

Historical notes: described by English botanist Sir William Turner Thiselton-Dyer (1843–1928), Assistant Director at Kew from 1875–1885 and Director from 1885–1905.

The presence of this distinctive species was first observed by Beddome (1869), who recorded it (with some hesitation) as *C. revoluta* Thunb. Thiselton-Dyer next noted in an popular article in Gardeners Chronicle in 1881 that a small-growing Indian species that was distinct from *C. circinalis* had several times been introduced into horticulture in Europe, under a variety of names. The first introduction was by Colonel Beddome, who sent plants to Belgian Nurserymen during his term as Director of the Government Gardens at Bangalore. These nurserymen applied the name *C. boddami* to the plants. The second introduction was by Adolf Haage of Erfurt, who gave the locality as Travancore. These introductions had the name *C. squamosa* applied to them. The third introduction was of plants collected by Colonel Puckle, another director of the Lal Bagh (Government Gardens) at Bangalore, and imported by the English plant trader William Bull in 1877, who described it is his catalogue as `a distinct Indian cycad, from the Presidency of Madras', under the name *C. pluma*. Thiselton-Dyer, while recording this history, appealed to readers (of Gardener's Chronicle) in southern India for botanical specimens from the wild, in order to establish the true relationships of this plant.

His pleas were answered by H.H. Yarde, the Deputy Conservator of Forests for the Cuddapah division, who sent both plants and botanical specimens. This allowed Thiselton-Dyer to recognise that this was a distinct species, and he described it as *C. beddomei* in 1883. Yarde apparently sent only juvenile plants, causing Thiselton-Dyer to firstly record that he had only seen stems a few inches high, and later (1888) to state categorically that stems were only a few inches high. The myth that this species was almost stemless was propagated in the literature from there, for example by Fischer (1928), Schuster (1932) and Raizada and Sahni (1960).

This species has been one of the few in the genus that has been fairly clearly understood from its beginning, with little misapplication of the name and no misunderstanding of the type. Schuster (1932) treated it as a variety of *C. circinalis*, to which it is clearly

closely related. However, he showed little understanding of the limits of *C. circinalis*, and included material from Java within his variety *beddomei*. Raizada & Sahni (1960) included material from the eastern Ghats that had been earlier separated as *C. circinalis* var. *orixensis* and *C. spherica* under *C. beddomei*. The Eastern Ghats material is, however, quite distinct from *C. beddomei* (see *C. spherica*).

Distinguishing features: this species has in common with the other southern Indian cycads a non-pectinate megasporophyll with subglobular seeds that display a distinctive fibrous layer within the sarcotesta, and an attenuate microsporophyll apex. It can be distinguished by the very narrow leaflets with revolute margins.

Distribution and habitat: known only from the Cuddapah Hills in Andhra Pradesh State, north-west of Madras in eastern Peninsular India (Fig. 1). Characteristically a species of dry, open hill slopes, in open woodland or grassland.

Conservation status: although present in considerable numbers, this species faces a number of significant threats. It is well adapted to rapid recovery after fire, but frequent grassfires effectively block reproduction by burning seeds and seedlings. An even more effective block to reproduction is the use of the male cones in Ayer Veda medicines, making them a trafficable commodity that can earn peasant villagers a few desperately needed rupees. The villagers scour the more accessible populations for cones, removing all before pollen shed. The species seems to be more widely distributed within the Cuddapah district than first thought. There are still several large undisturbed populations with annual seed production in more remote areas. However several large populations near the Tirupati have been destroyed by road work and now only exist as scattered individuals in inaccessible rock crevices. It is the only member of the genus *Cycas* to be listed in CITES Appendix 1, and is accorded a status of endangered. 1997 IUCN Red List of Threatened Plants category E (Walter & Gillet 1998). It is also protected within India by a Forestry Act completely ban the cultivation of this species. IUCN status **CR** (Donaldson 2003).

Selected specimens examined: INDIA: Andhra Pradesh: Cuddapah distr., Mogilipunta, *Gamble 21278*, Aug 1889 (K); Cuddapah Hills, *Higgins per Gamble 16597*, 1885 (K)

3. *Cycas circinalis* L., Spanish Pl.: 1188 (1753).

Type: the illustration: Rheede, Hort. Malab., tab. 19, 1682 (lecto, fide Stevenson in Jarvis et al. 1993).

Cycas circinalis var. *angustifolia* Miq., Comm. Phyt.: 125–126 (1840–1841). **Type:** ex hort. bot. Calcutta, U 028096 (lecto U).

Cycas wallichii Miq., Monogr. Cycad.: 32 (1842). **Type:** based on *Cycas circinalis* var. *angustifolia*.

Cycas undulata Desf. ex Gaudich., Voy. Uranie, Bot.: 434 (1829). *Cycas circinalis* [subsp. *circinalis*] forma *undulata* (hort. ex Gaudich.) J. Schust., Pflanzenr. 99: 66 (1932). *Cycas rumphii* forma *undulata* (Desf. ex Gaudich.) Kaneh., J. Jap. Bot. 14(9): 587 (1938). **Type:** hort. Paris, 1820, ex herb. Houllet (holo P).

[*Cycas circinalis* subsp. *vera* J. Schust., Pflanzenr. 99: 66–67, Fig. 40; 7C; 10A, F–G; 11F (1932); nom. illegit.]

[*Cycas hamelini* hort. ex J. Schust., Pflanzenr. 99: 66 (1932); name only, in syn. *Cycas circinalis*.]

[*Cycas kirkii* hort. ex J. Schust., Pflanzenr. 99: 73 (1932); name only, in syn. *Cycas circinalis*.]

Literature: Gaudichaud (1829), Trimen (1898), Stapf (1916), Leandri (1931), Ho & Duong (1960), Raizada & Sahni (1960), Suvatabandhu (1961), Smitinand (1971), Zamora & Co (1986), Hill (1995).

Illustrations: Anon. (1828), Miquel (1842), Griffith (1854) and as *C. jenkinsiana*, Warburg (1900), Schuster (1932) and as *C. rumphii* subsp. *zeylanica*, Smitinand (1971), Smitinand (1972), Zamora & Co (1986).

Etymology: from the Latin *circinus*, a spiral, in reference to the inrolled leaflets in developing leaves.

Vernacular: Hindi - *jangli-madan-mast-ka-phul* (lit. forest flower of sweet desire presumably ref. to aphrodisiac properties), Kanarese - *mundicalu*, Oriya - *orguna*, *odasa-mari*, Tamil - *cannngay* (lit. convulsions of the hand , possible ref. to toxic properties), *madanagama*, Telugu - *kamkshi*, *per ita*, Sanskrit - *varaguna* (Pant 1962, Bonta & Osborne 2005).

Stems arborescent, to 7 m tall, 12–27 cm diam.; growing in soil or humus; base not strongly swollen; bark thick and corky, cataphylls and leaf bases persistent. *Leaves* bright green, semiglossy, 150–270 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 54–110 leaflets, tomentum shedding as leaf expands or partly persistent; newly emerging leaves with a glaucous sheen. Petiole 34–70 cm long (20–40% of total leaf length), glabrous, spinescent for 30–100% of length; basal leaflets not gradually reducing to spines. *Median leaflets* simple, weakly discolorous, 220–360 mm long, 9–13 mm wide, narrowed to 2.5–4 mm at base (30–40% of maximum leaf width), 9–14 mm apart on rachis; section flat; margins flat, not undulate; apex softly acuminate, not spinescent; midrib raised above, flat below, narrow. *Cataphylls* narrowly triangular soft, thinly sericeous or lacking tomentum, 50 mm long. *Pollen cones* ovoid to conical, light brown to brown, 24–48 cm long, 12–18 cm diam., microsporophyll lamina firm, not dorsiventrally thickened, 45–60 mm long, 21–24 mm wide; fertile zone 40–55 mm long, sterile apex c. 5 mm long, merging with spine; apical spine prominent, gradually raised, 20–39 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 20–35 cm long, persistently orange-tomentose; ovules 4–14, glabrous; lamina lanceolate, 27–40 mm long, 23–34 mm wide, regularly dentate, with 10–28 pungent lateral spines 1–4 mm long; apical spine distinct from lateral spines, 14–34 mm long, 3–6 mm wide at base. *Seeds* elongated, 30–39 mm long, 20–24 mm wide; sarcotesta light yellow, fibrous layer absent; sclerotesta smooth; spongy endotesta absent.

Historical notes: surrounded by confusion since its inception, this was described as the single constituent species when the great Swedish botanist Carolus Linnaeus established the genus *Cycas* in 1753. He had, however, based his description on a number of earlier works that in fact covered at least three distinct species as we now know them. The subsequent history of this name has been one of total confusion. *Cycas circinalis* has subsequently appeared in the literature more frequently than any other *Cycas* combination, arguably without a single author wholly correctly applying the name. (See Table 2 for correct placement of combinations validly published under *Cycas circinalis*).

Of the eight references cited by Linnaeus, only two refer to *C. circinalis* as now typified. This reflects an increasing understanding of the systematics of the group since the time

of Linnaeus' work. The other species covered by Linnaeus' description are now known as *C. revoluta*, separated by Thunberg in 1784, and *C. rumphii*, separated by Miquel in 1839. The latter is part of a widespread species complex, all of which have been treated as part of *C. circinalis* at some time or other.

Table 2. Correct placement of combinations validly published under *Cycas circinalis*.

C. circinalis forma *glauca* (Miq.) Schust.	*C. glauca* Miq.
C. circinalis forma *gothanii* Schust.	Nom. dub.
C. circinalis subsp. *madagascariensis* (Miquel) Schust.	*C. thouarsii* Gaudich.
C. circinalis subsp. *madagascariensis* forma *trigonocarpoides* Schust.	*C. thouarsii* Gaudich.
C. circinalis subsp. *papuana* (F.Muell.) Schust.	*C. papuana* F.Muell.
C. circinalis subsp. *papuana* var. *scratchleyana* (F.Muell.)Schust.	*C. scratchleyana* F.Muell.
C. circinalis subsp. *riuminiana* (Port ex Regel) Schust.	*C. riuminiana* Port ex Regel
C. circinalis subsp. *riuminiana* var. *curranii* Schust.	*C. curranii* Schust.
C. circinalis subsp. *riuminiana* var. *curranii* forma *apertorum* Schust.	*C. riuminiana* Port ex Regel
C. circinalis subsp. *riuminiana* var. *curranii* forma *chamberlainii* (Brown & Keinholz) Schust.	*C. riuminiana* Port ex Regel
C. circinalis subsp. *riuminiana* var. *curranii* forma *graminea* Schust.	*C. wadei* Merrill
C. circinalis subsp. *riuminiana* var. *curranii* forma *maritima* Schust.	*C. edentata* de Laub.
C. circinalis subsp. *seemannii* (A.Braun) Schust.	*C. seemannii* A. Braun
C. circinalis subsp. *vera* var. *beddomei* (Dyer) Schust.	*C. beddomei* Dyer
C. circinalis subsp. *vera* var. *pectinata* (Griffith) Schust.	*C. pectinata* Buch.-Ham.
C. circinalis subsp. *thouarsii* (Gaudich.) Engl.	*C. thouarsii* Gaudich.
C. circinalis var. *javana* Miq.	*C. javana* (Miq.) de Laub
C. circinalis var. *orixensis* Haines	*C. spherica* Roxb.

Although well known in Indian culture for many centuries (Rheede 1682), the first reference to this species in Western writings was in Rheede's *Hortus Malabaricus*, published in Amsterdam in 1682. Although this publication has generally been accepted as the basis for this species (de Candolle 1868: 525, Stapf 1916, Wijnands 1986), it was not formally designated the type until 1993 (Jarvis et al.).

Much of the confusion associated with this species arises from the difficulty in recognising Miquel's segregate species *C. rumphii*, and its full geographic extent. Miquel himself had difficulty recognising the limits of these taxa (1868), and often changed his mind. Characteristics by which these species can be recognised were also not well known. The difficulty in separating the two has continued to the present (e.g. Jones 1993), and has severely reduced the usefulness and value of a number of anatomical and morphological studies based on unvouchered or cultivated materials (e.g. Dehgan & Yuen 1983, Pant 1973). Almost all plants in cultivation that have been known as *C. circinalis* in fact belong to the *C. rumphii* complex. The name *C. circinalis* has also been applied uncritically to local populations in many parts of the world, without real knowledge of the true nature of typical *C. circinalis*. Examples of misapplication occur in Ceylon (Trimen 1898 - *C. nathorstii*), Thailand (Suvatabandhu 1961, Smitinand 1971,

1972 - *C. spp.*), Malaysia (Gibbs 1914 - *C. edentata* de Laub.), The Philippines (Amoroso 1986, Foxworthy 1911, Zamora & Co 1986 - *C. riuminiana* Porte ex Regel), New Guinea (Borell 1989 - *C. apoa* K.D. Hill; Paijmans 1976 - *C. campestris* K.D. Hill; White 1922 - *C. scratchleyana* F.Muell.) and the western Pacific (Burkill 1901, de Laubenfels 1978, Hemsley 1895, Yuncker 1959 - *C. seemannii* A.Braun; Fosberg & Sachet 1975, Stone 1970 - *C. micronesica* K.D.Hill).

In the protologue of *C. circinalis*, Linnaeus (1753, 1754) cited treatments of *Cycas* from eight earlier works, including at least three taxa as they are currently circumscribed, but also stated 'Habitat in India'. Stapf (1916) stated '... the *C. circinalis* of India represented by Rheede's *Todda Panna* (Rheede 1682: 9, tab. 13–21), [is] the accepted basis of Linnaeus's species.' Lectotypification was discussed but not formally designated by Wijnands (1986). No specimens relating to Hortus Malabaricus are known, and one of the series of illustrations of *Todda Panna* by Rheede (tab. 19) has since been designated the lectotype by Stevenson in Jarvis et al. (1993).

A small population in the Annaikal hills near Palaghat has been described as *Cycas annakailensis* (Singh 2006, Singh & Radha 2006). This population lies within the range of *C. circinalis* (Fig. 1.). The description of this species compares it only with *C. circinalis* from the state of Kerala and not across the full range of *C. circinalis*, nor with *C. sphaerica* or *C. indica*. In addition, many of the distinguishing features cited overlap the same features in *C. circinalis* or are variable within the latter species. The smooth trunk cited also may be a feature of a wetter habitat, which encourages residual cataphylls and leaf bases to rot away. *C. annakailensis* is hence here treated as a distinct taxon on the basis of leaf differences (below), although it is acknowledged that further study of this group is required, particularly in the field.

Distinguishing features: characterised by a non-pectinate megasporophyll, and an attenuate microsporophyll apex (Fig. 2). This megasporophyll morphology occurs in many other species, and is largely the cause of much of the confusion. The attenuate microsporophyll state is, however, restricted to a few species from the Indian subcontinent. The broad and long leaflets easily distinguish this species from all other Indian species. *Cycas circinalis* is distinguished from other Indian species by the bluish new growth.

Distribution and habitat: *Cycas circinalis* is now known to be an Indian endemic, restricted to the Western Ghats, in the states of Kerala, Karnataka, Tamil Nadu, and the south of Maharashtra (Fig. 1). It typically occurs in fairly dense, seasonally dry scrubby woodlands in hilly areas. Many trees in this habitat lose their leaves in the dry season, and *C. circinalis* is also facultatively deciduous in extremely dry times. It appears to be an adaptable species with colonies extending from rocky hill outcrops down to coastal habitats at sea level.

The taxon from the northern Eastern Ghats in the state of Orissa, described as *C. circinalis* var. *orixensis* by Haines (1924) and generally treated as *C. circinalis*, differs markedly in its megasporophylls. It in fact represents a separate species (see *C. sphaerica*).

Conservation status: locally abundant in several areas, although the habitat has been severely reduced and degraded. Good populations still exist in a number of national parks and forest reserves. The local people in Kerala do not practice the devastating cutting of stems for medicine as in Tamil Nadu and Andha Pradesh. There are several

very large populations along the coast in Kerala that have been integrated within local villages and left undisturbed. Prolific seed set occurs and plants of every age and size class are present. IUCN status **DD** (Donaldson 2003).

Selected specimens examined: INDIA: Karnataka: Mangalore, *Debeaux* (P); *Metz 169a* (P); Presidency of Madras, Bellaru distr. [BELLARU, 13° 0'N, 76° 42'E.], Sandui forests, *Hooper per Gamble 11701*, May 1883 (K). **Kerala:** Kingdom of Malabar, South Malabar, near Tuppanad, *Fisher 2613*, 27 Feb 1911 (K); Kingdom of Malabar, interior de la peninsula, *Leschenault 814* (P); Quilon district, Aryankavu check point, N 08 .949333° E 77.15835° 242 m ASL, *Lindstrom 879, 880*, 16 Jan 2002, (NSW); 4 km from Palaruri waterfall, near the railway bridge, N 8.966311667° E 77.09265° 261 m ASL, *Lindstrom 887*, 16 Jan 2002 (NSW); *Lindstrom 882, 885, 886*, 16 Jan 2002, (NSW); Calicut district, between Kuningad and Purameri village, N 11.662115° E 75.64125° 26 m ASL. *Lindstrom 889*, 17 Jan 2002 (NSW); Calicut district, near Kuningad village, N 11.670667° E 75.6497° 34 m ASL, *Lindstrom 891, 892, 893*, 17 Jan 2002 (NSW); Cannanore, *herb. Wight 2756 pp*, Feb 1852 (K, P). **Tamil nadu:** South Travancore, Peckinpara Dam [Travancore is mainly now in Kerala, but this locality lies just across the border in Tamil Nadu, c. 8° 20' N 77° 20' E], *Ertanson 5398*, 14 Feb 1934 (NY).**Cult.:** Calcutta, *Meebold 756*, Feb 1905 (G); *Wallich 8587A* (K-W).

4. ***Cycas spherica*** Roxb., Fl. Ind.: 747 (1832).

Type: ex hort. Calcutta, *Roxburgh s.n.*, 1808 (lecto BM, fide Hill 1995).

Cycas circinalis var. *orixensis* Haines, Bot. Bihar Orissa 6: 1228 (1924). **Type:** India, Orissa, Mals of Puri, *Haines 5876*, June 1917 (syn. K); Angul, *Haines 5877*, July 1917 (syn. K).

Etymology: from the rounded seeds.

Stems arborescent, to 5 m. tall, 9–27 cm diam.; growing in soil or humus; base not strongly swollen; bark thick with persistent leaf bases and cataphylls. *Leaves* dark green, semiglossy, 95–185 cm long, flat (not keeled) in section,(opposing leaflets inserted at 180° on rachis), with 55–130 leaflets, with newly emerging leaves light green and lacking tomentum because tomentum sheds very early as leaf expands. Petiole 27–50 cm long (15–30% of total leaf length), glabrous, spinescent for 20–100% of length. Basal leaflets not gradually reducing to spines. *Median leaflets* simple, weakly discolorous, 180–270 mm long, 7–12 mm wide, narrowed to 3–4 mm at base (25–60% of maximum width), spaced at 12–22 mm on rachis; section flat; margins flat or slightly decurved, not undulate; apex softly acuminate, not spinescent; midrib raised above, raised below, narrow. *Cataphylls* narrowly triangular soft, thinly sericeous or lacking tomentum, 50–70 mm long. *Pollen cones* narrowly ovoid, orange, c. 45 cm long, c. 10 cm diam., microsporophyll lamina firm, not dorsiventrally thickened, 32–38 mm long; fertile zone 28–34 mm long, sterile apex c. 4 mm long, merging with apical spine; apical spine prominent, gradually raised, c. 17 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 20–25 cm long, persistently orange-tomentose; ovules 3–8, glabrous; lamina lanceolate, 28–43 mm long, 18–20 mm wide, shallowly pectinate or regularly dentate, with 21–25 pungent lateral spines 5–10 mm long; apical spine distinct from lateral spines, 17–29 mm long, 4–5 m wide at base. *Seeds* subglobose, 25 mm long, c. 25 mm wide; sarcotesta yellow, fibrous layer absent; sclerotesta smooth; spongy endotesta absent.

Historical notes: *Cycas spherica* was first mentioned by Roxburgh in 1814, and formally described by him in 1832. No type was cited, although reference was made

in the description to plants in cultivation in the botanic gardens in Calcutta, which were said to have been introduced from the Moluccas in 1798–9. *Cycas spherica* is not known from there, although much of the description clearly applies to this species. Roxburgh had evidently confused plants of *C. spherica* (at the time included in *C. circinalis*) and *C. rumphii* (which had not been described at that time) that were both growing in the gardens, and his description under the former name actually applies to the latter species. His description of *C. spherica* correspondingly applies mainly to the element cultivated as *C. circinalis*. Roxburgh did not retain a personal herbarium, but distributed his collections to other botanists. Roxburgh specimens thus do not always bear the names eventually published by him (Sealy 1975). Two Roxburgh collections from the Calcutta gardens now in BM represent *C. spherica* and *C. rumphii* respectively. The latter is annotated `*C. circinalis*', and the former bears only the annotation `*C. planifolia* Solander MS.'

This taxon was also described in 1924 as a variety of the closely-related *C. circinalis* by English forester Henry Haselfoot Haines (1867–1945), forester in India from 1888–1919, becoming Conservator of Forests for India. No type was cited, but Haines stated `Wild in the hill forests of the Mals of Puri, especially on the tops of ridges with heavy rainfall ! extending to Angul, in open forest, where it is less common ! Fl. July–Aug'. Haines' practise was to add the `!' when he had seen the plant in the wild in that locality, and does not always record the existence of a specimen.

Distinguishing features: this species is similar to *C. circinalis* in most respects, differing in the broader megasporophyll apex with longer teeth. (Fig. 2).

Distribution and habitat: *Cycas spherica* is from the Eastern Ghats in the state of Orissa in north-eastern and eastern peninsular India (Fig. 1), in dry forests and woodlands on hills.

Conservation status: poorly known. Donaldson (2003) status **DD.**

Selected specimens examined: INDIA: Orissa: Angul, *Haines 4033 pp (male)* (K); Puri, *Haines 4033 pp (female)* (K); "Hb Heyn", *Wallich 8587B* (K-W, K, LE); Presidency of Madras, Ganjam distr., Gullery [Galleri 20° 6' 0" N, 84° 34' 0" E], *Gamble 13749*, Jan 1884 (K); Gullery, *per Hooker & Thompson 101*, 1855 (P); Athmallik [Athamallik 20° 37' N 84° 27 'E], Hathidharablock, *Mooney 2867*, (7 May 18 or 19 47). **Tamil Nadu:** Hategada, *Gamble 13668*, Jan 1883 (K); Krishnagiri town, cult in town, *Lindstrom 856*, 9 Jan 2002 (NSW); between Krishnagiri and Bangalore. 4 km from Sapali, Godeene, N 12° 33.009', E 78° 11.522' 545 m ASL, *Lindstrom 857*, 9 Jan 2002 (NSW); between Krishnagiri and Reppomafi, N 12.6224667°, E 78.205017° 606 m ASL, *Lindstrom 859*, 9 Jan 2002 (NSW). **Karnataka:** Santebachilas, Thiryanaihalle, N 12° 44.009' E 76° 37.019' 1029 m ASL, *Lindstrom 862*, 10 Jan 2002 (NSW); ibid., N 12° 44.009' E 76° 37.019' 1029 m ASL, *Lindstrom 863*, 10 Jan 2002 (NSW); ibid., N 12 46.236" 076 34.839" 983 m ASL, *Lindstrom 864*, 10 Jan 2002 (NSW); ibid., N 12° 46.236' E 76° 34.839' 983 m ASL, *Liudstrom 865*, 10 Jan 2002 (NSW). **Andra Pradesh:** Palcondah [c. 13° 20' N 79° 30' E], *Cleghorn s.n.*, Sep 1953 (E); 5 km North of Mamandur, 27 km from Tiraputi. N 13° 43.609' E 79° 25.792' 380 m ASL., *Lindstrom 867*, 12 Jan 2002 (NSW); 5 km North of Mamandur, 27 km from Tiraputi. N 13° 43.330' E 79° 25.459' 331 m ASL, *Lindstrom 869*, 12 Jan 2002 (NSW); 5 km North of Mamandur, 27 km from Tiraputi, N 13° 43.330' E 79° 25.459' 331 m ASL, *Lindstrom 870*, 12 Jan 2002 (NSW); 5 km North of Mamandur, 27 km from Tiraputi. N 13° 43.330' E 79° 25.459' 331 m ASL, *Lindstrom 871*, 12 Jan 2002 (NSW); Pulney Hills [KODAIKANAL 10° 14' N 77° 29' E], *Sauliere 827* (K); Madurai distr., lower Pulneys, *Anglade 1028* (K); Maradai Hills, *Gamble 14597* (K); Madurai dist. Alagarkoil Range, Uppodapatti village, *Lindstrom 878, 876*, 15 Jan 2002 (NSW).

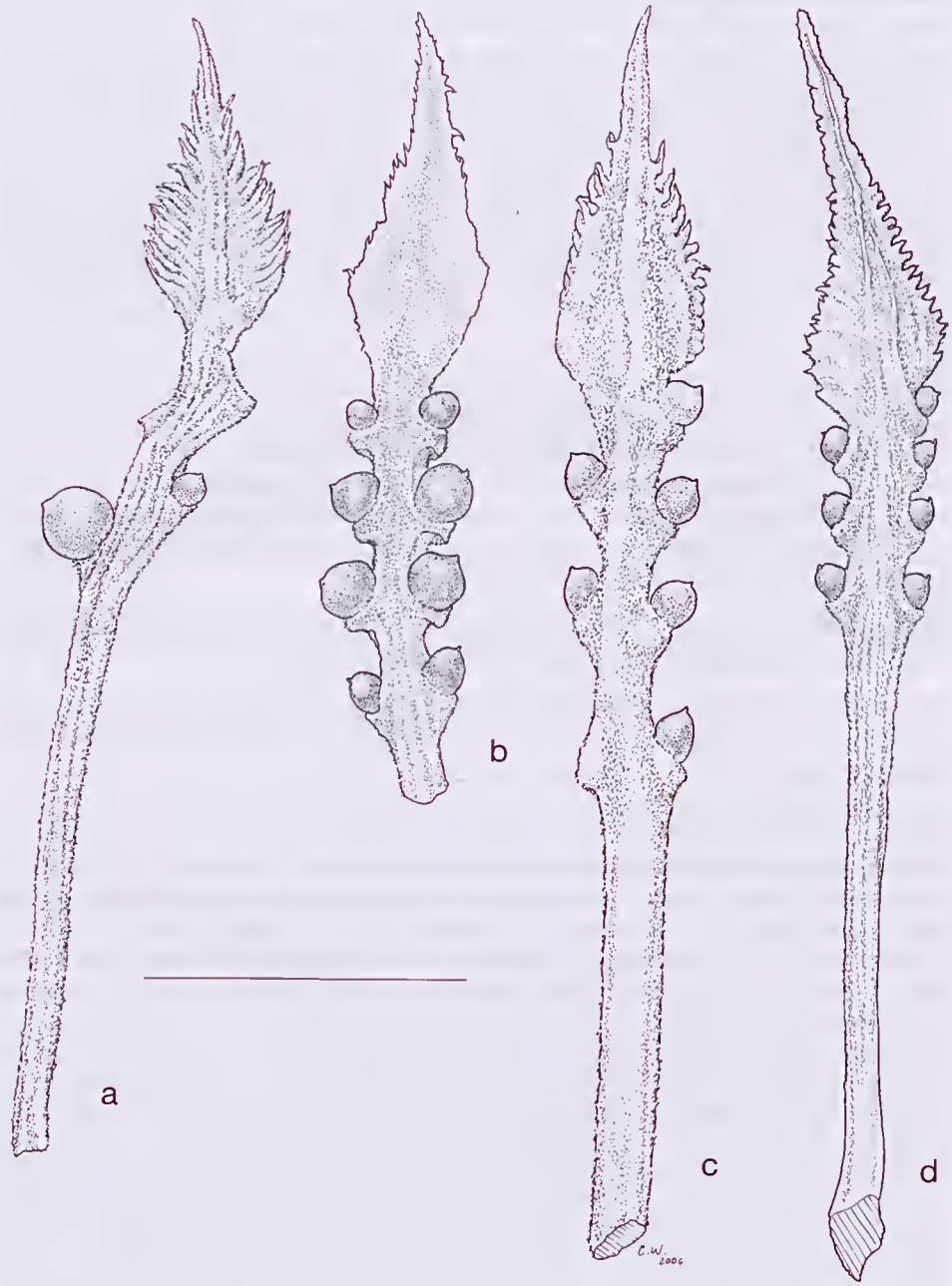

Fig. 2. Comparison of female sporophylls. **a,** *C. spherica*, **b,** *C. indica*, **c,** *C. circinalis*, **d,** *C. nathorstii*. (a from *Haines 5877* (K), b from *Cameron s.n.* 10 Mar 1882 (K), c from image of *Lindstrom 891*, d from *Thwaites 3689*). Scale bar: a, b, c, d, = 5 cm.

5. ***Cycas annaikalensis*** Rita Singh and P.Radha (Singh & Radha, Brittonia 58(2): 119–123 (2006).

Type: India, Kerala, Palaghat, Annaikal hills, 940 m, *Rita Singh, P. Radha and Prabha Sharma (0491) 0144*, May 2003 (holo IPUH (CAL), iso DD).

Etymology: the specific epithet refers to the name of the locality, Annaikal hills where this population is located. In Malayalam, *annai* = elephant, and *kal* = rock.

Stems arborescent, approximately 5 m tall, 19–61 diam.; bark smooth, steel greyish without any persistent armour of leaf bases, cataphylls and leaf bases not persistent. *Leaves* bright green, semiglossy, 100–250 cm long, flat (not keeled) in section (opposing leaflets inserted at 180° on rachis), with 200–240 leaflets, tomentum shedding as leaf expands.. Petiole 50–90 cm long, spinescent for 100% of length, spines 0.9–3 mm long. Basal leaflets not gradually reducing to spines. *Median leaflets* simple, weakly discolorous; 260–350 mm long, 8–12 mm wide, inserted at 50–55° to rachis; section flat; margins flat, not undulate; apex softly acuminate, not spinescent; midrib raised above, flat below, narrow. *Cataphylls* narrowly triangular, soft, thinly sericeous or lacking tomentum. *Pollen cones* sub-conical, yellowish orange prior to dehiscence, 30–50 cm long, 15–21 cm diam., microsporophyll lamina firm, not dorsiventrally thickened, 63–83 mm long, 18–26 mm wide, fertile zone 20–32 mm long, sterile apex 38–47 mm long, gradually raised and merging into spine. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 9–25 cm long, persistently densely ferruginous-tomentose; ovules 2–10, glabrous; lamina triangular, 19–55 mm long, 13–40 mm wide, regularly dentate with 5–18 lateral spines 5–8 mm long, apical spine distinct from lateral spines, 3–25 mm long, 4–7 mm wide at base. Seeds 2–10 globose, 38–49 x 35–43 mm, sarcotesta green when young, becoming yellow at maturity, fibrous layer absent, sclerotesta smooth, spongy endotesta absent.

Historical notes: distinguished as a separate species during field surveys (2001–2004) by Indian botanist Rita Singh.

Conservation Status: *Cycas annaikalensis* occurs within the hilly forest region of Palaghat district, but the identity of the other sporadic populations in the vicinity of the type locality are yet to be confirmed. *Cycas annaikalensis* must be currently regarded as Data Deficient (DD) according to IUCN (2001).

Distinguishing features: *Cycas annakailensis* differs from *C. sphierica* and *C. circinalis* in having steel grayish smooth trunk, the higher number of leaflets, the angle of attachment of the median leaflets to rachis and the larger microsporophyll. It differs from *C. indica* in the same features, and in the possession of a megasporophyll with a distinct terminal spine.

Distribution and habitat: *Cycas annaikalensis* is currently described from a single population of less than 100 individuals over an area of 100–250 m^2 on the Annaikal hills near Palaghat at an altitude of 940 m. Plants grow as an understorey element on steep slopes of coarse black humus soil with a thick canopy of tropical flowering trees. Assessing the habitat, it is assumed that this species may also occur in adjacent Reserve Forest areas, but comprehensive exploration has yet to be done to assess the number of populations and plants occurring in the region.

Selected specimens: INDIA: Kerala: Palaghat district, Annaikal, Oct 2001, 940 m *Rita Singh, P. Radha & Prabha Sharma, 0491, 0041–0052*; May 2003, *Rita Singh & P.Radha (0491) 0075, 0076, 0118, 0119, 0120* (all IPUH);

6. ***Cycas nathorstii*** J. Schust., *Pflanzenr.* 99: 76, Fig. 10E (1932).

Type: Sri Lanka, central and northern parts of the isle, *Thwaites 3689 in Herb. Barbey-Boisser,* 1866 (lecto here designated G, (female only); isolecto A, K, LE, P, fide Lindstrom 2002). This specimen was designated as the lectotype in Lindstrom and Hill (2002), however the specimen is comprised of male and female components and thus represents separate plants. This error is here corrected.

Etymology: honouring Swedish palaeobotanist Alfred Gabriel Nathorst (1850–1921), professor at the Natural History Museum in Stockholm.

Vernacular: Sinhala - *madu* (Schuster 1932, Bonta & Osborne 2005).

Stems arborescent, to 4.5 m tall, 11–20 cm diam.; growing in soil or humus; base not strongly swollen; bark thick with persistent cataphylls and leaf bases. *Leaves* bright green, semiglossy, 160–180 cm long, flat (not keeled) in section, (opposing leaflets inserted at 180° on rachis), with 140–170 leaflets, tomentum shedding as leaf expands; newly emerging leaves bright green, tomentum shedding early. Petiole 45–55 cm long (25–30% of total leaf), glabrous, spinescent for 90–95% of length. Basal leaflets not gradually reducing to spines, 65–140 mm long. *Median leaflets* simple, weakly discolorous, 190–310 mm long, 9–14 mm wide, narrowed to 3–4 mm at base (to 25–45% of maximum width), 17–20 mm apart on rachis; inserted at 55–80° to rachis; section flat; margins flat; apex softly acuminate, not spinescent; midrib raised above, raised below. *Cataphylls* narrowly triangular, soft, thinly sericeous or lacking tomentum, 50–60 mm long. *Pollen cones* narrowly ovoid, orange, c. 45 cm long, c. 15 cm diam.; microsporophyll lamina firm, not dorsiventrally thickened, 30–40 mm long, 15–22 mm wide, fertile zone 25–35 mm long, sterile apex c. 5 mm long; apical spine prominent, gradually raised, c. 10 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 15–30 cm long, persistently brown tomentose; ovules 6–10, glabrous; lamina lanceolate, 40–65 mm long, 18–25 mm wide, shortly dentate with 26–40 lateral spines 1–4 mm long; apical spine distinct from lateral spines, 10–14 mm long, 4–8 mm wide at base. *Seeds* to 55 mm long, to 40 mm wide, flattened-ovoid; sarcotesta yellow, fibrous layer absent; sclerotesta smooth; spongy endotesta absent.

Historical notes: the upland cycad from Sri Lanka has been generally known as *C. circinalis* (Trimen 1898), and was in fact one element of the protologue of the latter (Linnaeus 1753; Fl. Zel.). German historian and sometime botanist Julius Schuster distinguished *C. nathorstii* from *C. circinalis* in 1932 on the basis of specimens collected by George Thwaites and distributed to European herbaria by Swiss botanist and philanthropist William Barbey-Boissier (1842–1914). Thwaites (1812–1882) was superintendent of the Royal Botanic Garden at Peradeniya in Ceylon from 1849–1880. Collection detail cited was "Ceylon: Thwaites 1866 n. 3689 in Herb. Barbey-Boissier." The Barbey-Boissier herbarium and types are in G, including this specimen. This may not have been the specimen examined by Schuster, as it has no annotation by him and was filed as undetermined. Schuster's types were mainly in B, and were destroyed during WW2. This sheet includes both leaflets and megasporophylls, and is here designated the lectotype. Schuster's work has been largely (rightly) ignored, including this taxon, although, in this case, a valid distinction exists.

De Laubenfels and Adema (1998) included *C. nathorstii* in the synonymy of *C. spherica*, but also placed some Sri Lankan collections of the same taxon in *C. circinalis.*

Distinguishing features: distinguished from *C. circinalis* and *C. spherica* by the more

robust habit, narrower, dull leaflets and larger male cones with longer and more curved apical spines on microsporophylls. *C. nathorstii* is distinguished from *C. zeylanica* by the more closely spaced and more chartaceous leaflets, the shorter, softer and less pilose cataphylls and lack of spongy endotesta. It is distinguished from *C. circinalis* by the bright green new growth, whereas new growth is bluish *in C. circinalis.*

Distribution and habitat: *C. nathorstii* occurs in inland and upland forests in the north of Sri Lanka, and on flat land in the east of Tamil Nadu in India (Fig. 1), usually in somewhat drier sites.

Conservation status: India: like all cycads in Tamil Nadu this species has suffered greatly from stem cutting for local medicine. Several populations have been depleted to only a very few scattered individuals. As the lowland is very attractive agricultural land populations have been destroyed to make way for human populations. It must be regarded as Endangered (IUCN 2001 Red List category **EN**). **Sri Lanka:** Still locally frequent, although not in great numbers, this species is regarded as vulnerable (IUCN 2001 Red List category **VU**). It is known to be present in reserves, but political instability makes assessment difficult and future status uncertain.

Selected specimens examined: INDIA: Tamil Nadu: Chuingleput distr. [CHINGLEPUT 12°42' N 79° 59' E],"Madras" *Gamble 17052*, Nov 1885 (K); Pattamcattah [? PATTUKKOTTAI 10° 26' N 79° 19' E], *herb Wight 2756 pp*, Oct 1835 (K, LE, G); 4 km from Tiruporor towards Changelpet, N 12° 42.842' E 80° 09.394' 24 m ASL, *Lindstrom 896*, 18 Jan 2002 (NSW); Tamil Nadu, 4 km from Tiruporor towards Changelpet, N 12° 43.047' E 80° 09.278' 17 m ASL, *Lindstrom 897*, 18 Jan 2002 (NSW). **SRI LANKA:** between Kuda Patessa and Maha Patessa, *Cooray & Wirawan 1145*, 15 Jul 1969 (A, K, L, NY); NW Province, Puttalam district, Wilpattu National Park, Kudu patassa, *Davidse 8237 & Sumithraarachi*, 1 Nov 1974 (BRI, K, L); 2 miles [3.2 km] E of Bible, *Fosberg & Sachet 53148*, 28 Nov 1970 (K, NY); Manerangata district, Bibile, *Hepper & de Silva 4723*, 18 Jul 1972 (K); Ceylon, *herb. P. Herm.* (L); ridge S of Na-Ulpota, *Jayasuriya 1278*, 8 Aug 1973 (K); Moraragale district, Nilgala, Gal Oya National park, *Jayasuriya 1951*, 1 May 1975 (L); Gampaha district, N of Gampaha, NE of Dunagaha, Diwulepitiya, Rassapana village, *Lindstrom s.n. (NSW 440049)*, 1997 (NSW); Mandae, *Oldmanas 53* (L); hort. Kew. ex Ceylon, *Thwaites 423*, 1875 (K).

7. *Cycas indica* A.Lindstrom & K.D.Hill, ***sp. nov.***

A *Cycade circinali* megasporophyllis reductis spinis apicalibus lateralibusque reductis, caudice surculari differt.

Type: India: Mysore, Hassan distr., Nagpuri, Chick Tirupathii, *Saldanha 15197*, 8 Oct 1970 (E).

Etymology: the epithet is in reference to the species endemic occurrence in India.

Stems arborescent, to 4 m tall, 10–23 cm diam.; growing in soil or humus; base not strongly swollen; bark thin and smooth, cataphylls and leaf bases persistent. *Leaves* deep green, semiglossy, 97–133 cm long, flat (not keeled) in cross-section, (opposing leaflets inserted at 180° on rachis), with 50–71 leaflets, indumentum present on petiole and leaflets. Petiole 28–32 cm long (25–35% of total leaf length), spinescent for 30%–90% of length. Basal leaflets not gradually reducing to spines, 72–110 mm long. *Median leaflets* simple, discolorous, 120–240 mm long, 7–8 mm wide, narrowed to 3–4 mm at the base (35–50% of total width), spaced at 12–15 mm on rachis; margins flat; midrib raised above, flat below. *Cataphylls* narrowly triangular, soft, very finely tomentose, 50–80 mm long. *Pollen cones* narrowly ovoid, yellow, c. 30–40 cm long, c. 15 cm diam.; microsporophyll

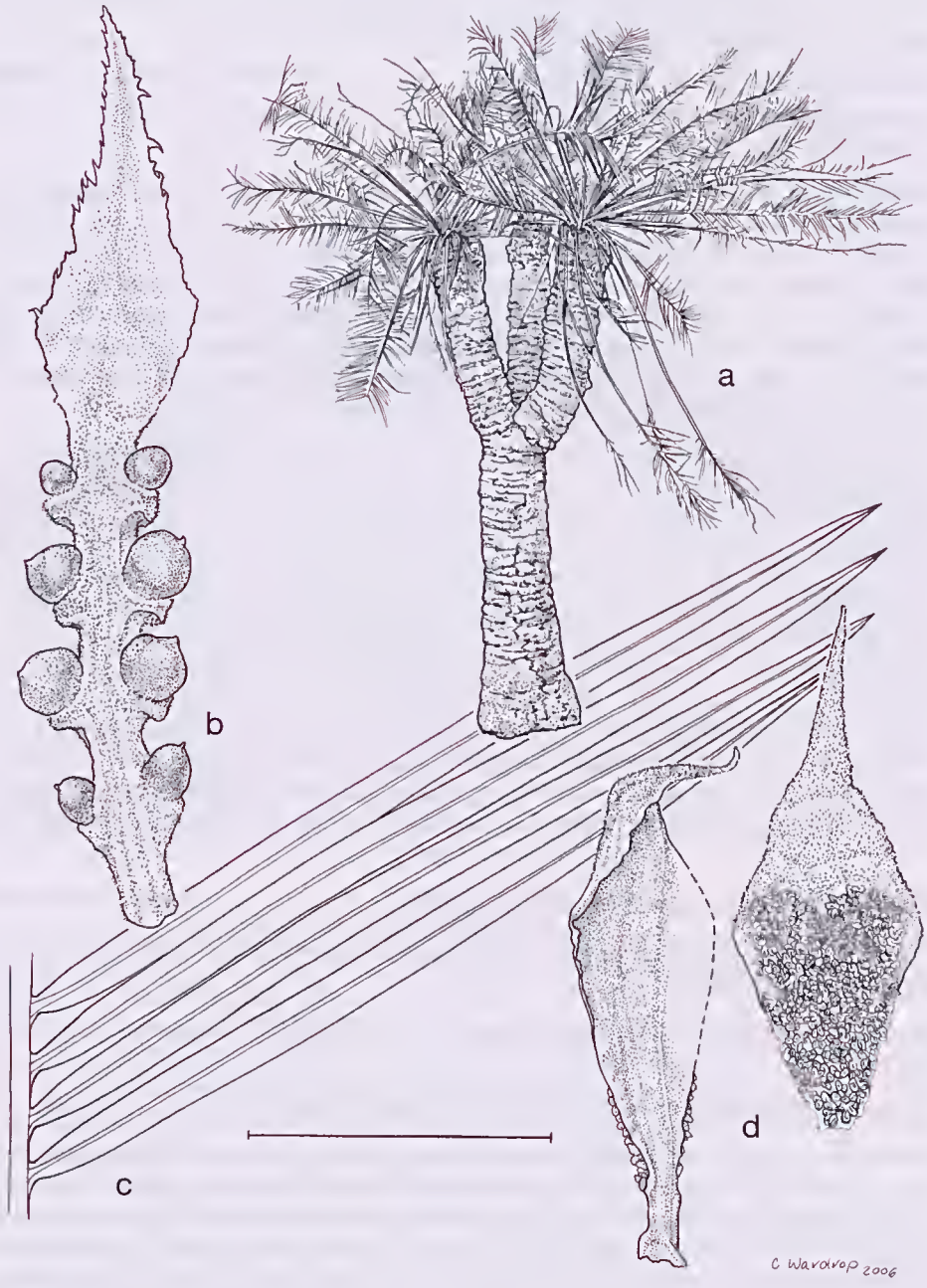

Fig. 3. *Cycas indica.* **a,** sketch of habit. **b,** female sporophyll. **c,** part of leaf. **d, e,** male sporophyll. (a from *Lindstrom 864* slide, b from *Cameron s.n.* 10 Mar 1882 (K), c d e from *Saldanha 15197*) Scale bar: a = No scale, b = 4 cm, c= 5.45 cm, d= 3 cm, e = 3cm.

lamina firm, not dorsiventrally thickened, c. 66 mm long, c. 28 mm wide, fertile zone c. 23 mm long, sterile apex merged with spine, apical spine prominent, sharply upturned, c. 41 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 18 cm long, brown tomentose; ovules 6, glabrous; lamina 25–55 mm long, 19–22 mm wide with less than 10 short irregular lateral spines to 2 mm long; apical spine not distinct from lateral spines, 1–3 mm long, 1–3 mm wide at base. *Seeds* globose, 32–35 mm long, 28–30 mm wide; sarcotesta yellow at maturity, fibrous layer absent; sclerotesta smooth; spongy endotesta absent (Fig. 3).

Historical notes: this is the entity that has been referred to in literature (Pant 1962, 1973; Singh 2006) as *Cycas circinalis* var. *swamyi*, but this name has never been validly or legitimately published. Reference has been made to the abnormal branching habit (Pant 1962, 1973), but no rigorous comparisons have been made with *C. circinalis* growing in other localities.

Distinguishing features: similar to *C. circinalis* but distinct in the short apical spine and compact lamina with few, short (or almost lack of) lateral spines on the megasporophyll (Fig. 2), the shorter and narrower leaflets, overall shorter leaves and a distinct suckering growth habit. It shares the globose seeds with *C. sphaerica*.

Distribution and habitat: restricted to the Hassan district in Karnataka State (Fig. 1). Common on flat sandstone or on quartzite-dominated areas. This species forms extensive colonies.

Conservation status: not known (**DD** – IUCN 2001).

Selected specimens examined: INDIA: Karnataka: 20 to 35 miles from Bangalore, "where ranges of Western Ghats meet tablelands", *Cameron s.n.* (K - 3 sheets, dated 4 Mar 1884, 10 Mar 1882 and Apr 1884); Mysore, *Buchanan per Wallich 8587B* (K, BM).

Subsection Rumphiae K.D.Hill, Austral. Syst. Bot. 7: 548 (1994).

Type: *C. rumphii* Miq., Bull. Sci. Phys. Nat. Neerl. 2: 45 (1839).

This subsection is uniquely defined by the presence of a layer of spongy tissue within the seed. Another potentially synapomorphic character defining this group is the 2-year seed maturation period, although this has been confirmed only for *C. seemannii*, *C. thouarsii* and *C. bougainvilleana* K.D.Hill. All other species of *Cycas* for which data is available have a maturation period of less than one year.

Distribution is very wide, extending from Africa to Fiji and Tonga, and from New Guinea north to southern coastal Indochina. One species occurs in India, in the Andaman and Nicobar islands only.

Taxonomy of the group is difficult, and all species in the *C. rumphii* complex have appeared in the literature erroneously as *C. circinalis* at some stage (see Hill 1994).

The spongy endotesta causes seeds to be buoyant, and has been proposed as a dispersal mechanism (Dehgan and Yuen 1983). This dispersal mechanism has been interpreted as a cause of the taxonomic complexity of this group, with successive colonisation events producing the high local variability in some populations and the very different forms sometimes occurring in close proximity (Hill 1994, Fosberg and Sachet 1975).

8. *Cycas zeylanica* (J. Schust.) A. Lindstrom & K.D. Hill, Novon 12(2): 238–239 (2002).

Cycas rumphii subsp. *zeylanica* J. Schust., *Pflanzenr.* 99: 75, Fig. 10 C–D, 11 M (1932).

Type: Sri Lanka, 1866, *Thwaites 3862 in Herb. Barbey-Boissier* (lecto G, (female only) isolecto A, K, LE) (Lindstrom & Hill 2002).

Literature: Trimen 1898 (as *C. rumphii*), Rendle 1900 (as *C. rumphii*), Raizada & Sahni 1960 (as *C. rumphii*).

Etymology: from Zeylona, the Latinised rendering of Ceylon (Sri Lanka), from where the type of this species was collected.

Vernacular: Maha-madu (Sri Lanka).

Stems arborescent, 2.3–3.1 m tall, 13–20 cm diam.; growing in soil or humus; base not strongly swollen; bark thin and smooth; (with c. 30 leaves in crown), cataphylls and leaf bases not persistent. *Leaves* bright to deep green, semiglossy, 140–190 cm long, flat (not keeled) in section, (opposing leaflets inserted at 180° on rachis), with 70–100 leaflets, with white or orange tomentum shedding as leaf expands; rachis consistently terminated by paired leaflets. Petiole 50–70 cm long (30–40% of total leaf), glabrous, spinescent for 30–100% of length. Basal leaflets not gradually reducing to spines, 190–200 mm long. *Median leaflets* simple, strongly discolorous, inserted at 50–60° to rachis, 180–300 mm long, 12–15 mm wide, narrowed to 6–7 mm at base (to 40–50% of maximum width), 22–27 mm apart on rachis; section flat; margins slightly recurved; apex acute, not spinescent; midrib raised above, flat below. *Cataphylls* linear, pungent, pilose, 100–120 mm long. *Pollen cones* fusiform, orange-brown, c. 30–40 cm long, c. 10 cm diam.; microsporophyll lamina firm, dorsiventrally thickened, 35–45 mm long, 17–19 mm wide, fertile zone 30–40 mm long, sterile apex 3–5 mm long; apical spine prominent, sharply upturned, 3–10 mm long. *Seed cones* open at pollination, open at seed set. *Megasporophylls* 17–30 cm long, persistently brown tomentose; ovules 2–4, glabrous; lamina lanceolate, 60–120 mm long, 10–17 mm wide, obscurely dentate with 6–12 lateral bumps or short spines to 2 mm long; apical spine distinct from lateral spines, 40–60 mm long, 3–7 mm wide at base. *Seeds* flattened-ovoid, 60–70 mm long, 45–55 mm wide; sarcotesta orange-brown, fibrous layer absent; sclerotesta smooth; spongy endotesta present.

Historical notes: collection detail cited was "Ceylon: Thwaites 1866 n. 3862 in Herbar. Barbey-Boissier." Schuster's herbarium and types were in B, and were destroyed in WW2. The Barbey-Boissier herbarium and types are in G, including this collection. Three sheets exist, with microsporophylls, megasporophylls and leaflets, each on a separate sheet. More than one plant is clearly involved, and it is impossible at this stage to associate the leaf specimen with either of the fertile specimens. These may not have been the specimens examined by Schuster, as they have no annotations. The sheet bearing the megasporophylls has been designated the lectotype.

Distinguishing features: allied to both *C. thouarsii* and *C. edentata*, sharing the characters of seeds lacking an apical wing and microsporophylls with an apical spine. *Cycas zeylanica* is distinguished by the abundant long and pungent cataphylls and widely spaced leaflets.

Distribution and habitat: known from Sri Lanka, where apparently now a rare species in southern coastal regions, and the Andaman and Nicobar groups, where more abundant (Fig. 1). The habitat is in littoral forest near the sea in sandy soil.

Conservation status: India. The species is widespread and common on the Andamans and Nicobar islands. But although still growing in large populations at several locations, severe damage has been done by repeated strong cyclones. The recent development of seaside resorts on the islands has also had an impact on some populations and several previously large populations have been eradicated to make space for tourist accommodations. There are populations within protected areas as well as in off-limit, military areas. Recommended IUCN Red List category would be Vulnerable (**VU** - IUCN 2001). **Sri Lanka.** Populations have been totally destroyed and a survey done by the first author failed to find any viable regenerating populations. Only widely scattered, large, old specimens remained. No plants were found within any protected areas. The 2005 tsunami hit the coast of Sri Lanka and seriously damaged the only known narrow strip of land where the last scattered individuals existed. Although no recent post tsunami survey has been conducted it is very likely that most if not all remaining plants are now dead, either by direct hit of the wave and debris or bulldozed by the cleaning crew. The correct IUCN Red List category for the species on Sri Lanka should be Critically Endangered (**CR**) or possibly Extinct (**EX**). (IUCN 2001).

Selected specimens examined: INDIA: South Andaman, *Kurz s.n.* (K, P); hort. Kew, raised from seed coll. Nicobars by Col. Nan in 1875, *leg. ign.*, 1881 (K); South Andaman, *Liebig s.n.* (E); Havelock island, E. coast, beach No. 5, 2 m ASL, tall evergreen littoral forest, app. 50 m from the beach, *Lindstrom 357*, 2 Dec 2000 (SING), cult. near the jetty, 5 m ASL, *Lindstrom 359*, 2 Dec 2000 (SING); W. coast, beach No.7, 3 m ASL, tall secondary evergreen littoral forest, *Lindstrom 365* , 3 Dec 2000 (SING); Kodiaghat, beach vegetation, sandy soil, sea level, few plants, *Bulakrishnan 382*, 25 Sep 1973 (SING); Rangat, Middle Andaman, *Kirit Ram 3806*, Feb–Mar 1934 (E). **SRI LANKA:** Araiya Mawtha, Maddawattha, Mataya, wild near the seashore along a stream, 27 m ASL, *Lindstrom 287*, 10 Jun 2000 (SING); cultivated along the road, 31 m ASL, *Lindstrom 288*, 10 Jun 2000 (SING); Hikkaduwa, Dewadalla, Wauleguda, cult. *Lindstrom 289*, 11 Jun 2000 (SING); Wtage, Alangama, cult., 11 Jun.2000 *Lindstrom 290* (SING); cult. Peradinya, *Lindstrom s.n.*, 1997 (*NSW 440048*) (NSW).

Acknowledgments

Mr. Kampon Tansacha, the owner and Director of Nong Nooch Tropical Botanical Garden, Thailand is most gratefully acknowledged for his relentless encouragement and full sponsorship of the field trips. The Slade Foundation of Sydney is also thanked for assistance with travel and field studies. The staff of the Royal Botanic Gardens, Sydney, have been of invaluable assistance, and this would not have been published without them, Leonie Stanberg in particular. Illustrations are by Catherine Wardrop and Lesley Elkan. Peter Wilson is thanked for assistance with Latin. Juliet Wege is thanked for locating specimens at Kew while Australian Botanical Liaison Officer.

References

Amoroso VB (1986) Morphological study of the sporophylls of Philippine *Cycas*. *Philippine Journal of Science* 115(3): 177–198.

Anon. (1828) *Botanical Magazine* 55: t. 2826, 2827.

Beddome RH (1869) *The forester's manual of botany for southern India.* (Gantz Bros: Madras)

Bonta M & Osborne R (2007) Cycads in the Vernacular in Osborne R (ed.) *Proceedings of the Seventh International Conference on Cycad Biology. Memoirs of New York Botanical Garden Vol. 99* (in press).

Borell GW (1989. *An annotated checklist of the flora of Kairiru Island, New Guinea.* (Borell, Marcelin College: Victoria)

Burkill J (1901) The flora of Vavua, one of the Tonga islands. *Journal of the Linnaean Society, Botany* 35(242): 20–65.

Chen CJ, Zhou L, Yang SY & Han ZS (1995) *Cycas* in China, with notes on its conservation status. Pp. 177–191 in Vorster P (ed.) *Proceedings of the Third International Conference on Cycad Biology.* (Cycad Society of South Africa, Stellenbosch)

Chen CJ & Stevenson DW (1999) Cycadaceae. Pp. 1–7 in Wu ZY & Raven PH (eds) *Flora of China*, vol 4. (Science Press, Beijing & Missouri Botanical Garden Press: St Louis)

Cheng WC, Fu LK & Cheng CY (1975) Gymnospermae Sinicae. *Acta Phytotaxonomica Sinica* 13(4): 81–82.

De Candolle AP (1868) Cycadaceae. Pp. 522–548 in de Candolle AP (ed.) *Prodromus Systematis Naturalis Regni Vegetabilis* 16(2). (Treuttel et Wurtz: Paris)

De Laubenfels DJ & Adema F (1998) A taxonomic revision of the genera *Cycas* and *Epicycas* gen. nov. (Cycadaceae). *Blumea* 43: 351–400.

De Laubenfels DJ (1972) Cycadaceae. Pp. 3–7 in Humbert H & Leroy J-F (eds) *Flore de Madagascar et des Comoros: Gymnospermes.* (Museum Nationale D'Histoire Naturelle: Paris)

Dehgan B & Yuen CKH (1983) Seed morphology in relation to dispersal, evolution and propagation of *Cycas*. *Botanical Gazette* 144(3): 412–418.

Donaldson, J. S. (ed.) (2003) Cycads. Status Survey and Conservation Action Plan. IUCN/SSC Cycad Specialist Group (IUCN: Gland and Cambridge)

Fischer CEC (1928) *Flora of the presidency of Madras.* (Adlard & Son: London)

Fosberg FR & Sachet M-H (1975) Flora of Micronesia, 1: Gymnospermae. *Smithsonian Contributions to Botany* 20: 1–15.

Foxworthy FW (1911) Philippine gymnosperms. *The Philippine Journal of Science* 6(3): 149–152

Gaudichaud-Beaupre C (1829) Botanique. Pp. 432–441 in de Freycinet L *Voyage autour du monde, S.M. Uranie.* (Pillet: Paris)

Gibbs LS (1914) Cycadaceae. In a contribution to the flora and plant formations of Mount Kinabalu and the highlands of British North Borneo. *Journal of the Linnean Society, Botany.* 42(285): 1–240.

Grierson AJC & Long DG (1983). *Flora of Bhutan*, vol. 1. (Royal Botanic Gardens Edinburgh: London)

Griffith W (1854a) *Notulae ad Plantas Asiaticas*, vol. 4. (Bishops College Press: Calcutta)

Griffith W (1854b) *Icones plantarum asiaticum*, vol. 4. (Coshan: Calcutta)

Haines HH (1924) *The Botany of Bihar and Orissa* 6: 1228. (Adlard: London)

Hamilton F (1826) Commentary on the Herbarium Amboinense. *Memoirs of the Wernerian National Historical Society* 5(2): 322–324.

Hemsley WB (1895) Descriptions of some new plants from eastern Asia, chiefly from the island of Formosa, presented by Dr. Augustine Henry, F.L.S., to the Herbarium, Royal Gardens, Kew. *Annals of Botany* 33: 143–160

Hill KD & Yang SL (1998) The genus *Cycas* (Cycadaceae) in Thailand. *Brittonia* 51: 48–73.

Hill KD (1994) The *Cycas rumphii* complex (*Cycadaceae*) in New Guinea and the Western Pacific. *Australian Systematic Botany* 7(5): 3–567.

Hill KD (1995) The genus *Cycas* (Cycadaceae) in the Indian region, with notes on the application and typification of the name *Cycas circinalis*. *Taxon* 44: 23–31.

Hill KD (1995) Infrageneric relationships, phylogeny and biogeography of the genus *Cycas* (Cycadaceae). Pp 139–162 in Vorster P (ed.) *CYCAD 93, The 3rd International Conference on Cycad Biology, Proceedings.* (Cycad Society of South Africa: Stellenbosch)

Hill KD (1998) The Cycad Pages. Royal Botanic Gardens Sydney. http://plantnet.rbgsyd.nsw.gov.au/PlantNet/cycad/index.html

Hill KD (2004a) Character evolution, species recognition and classification concepts in the Cycadaceae. Pp. 23–44 in Walters T & Osborne R (eds) *Cycad classification concepts and recommendations.* (CABI Publishing: Wallingford)

Hill KD (2004b) An analysis of morphological characters used in classification of the Cycadaceae. Pp 6–29 in Lindstrom AJ (ed.) *The Biology, Structure & Systematics of the Cycadales Proceedings of the Sixth International Conference on Cycad Biology, Thailand, 29 July–3 Aug, 2002.* (The Nong Nooch Tropical Botanical *Garden*: Sattahip)

Hill KD & Vatcharakorn P (1998) The Cycads of Thailand. Pp. 178–190 in Hodel DR (ed.) *The Palms and Cycads of Thailand.* (Kampon Tansacha, Nong Nooch Tropical Garden: Thailand)

Ho P & Duong N (1960) *Cay-co mien nam Viet-nam.* (Ministry of National Education: Saigon)

IUCN (2001) *IUCN Red List Categories and Criteria : Version 3.1.* IUCN Species Survival Commission. (IUCN: Gland)

Jarvis CE, Barrie FR, Allan DM & Reveal JL (1993) A list of Linnaean generic names and their types. *Regnum Vegetabile* 127, 1–100.

Jones DL (1993) *Cycads of the World.* (Reed: Chatswood)

Kurz S (1877) *Forest flora of British Burma*, vol 2. (Government printer: Calcutta)

Leandri J (1931) Cycadaceae. Pp. 1085–1092 in Lecomte MH & Gagnepain F (eds) *Flore Generale de L'Indo-Chine*, vol. 5. (Masson et Cie: Paris)

Lindstrom AJ & Hill KD (2002) Notes on the species of *Cycas* (Cycadaceae) from Sri Lanka and Islands of the Andaman Sea. *Novon* 12: 237–240.

Lindstrom AJ (2002) Circumscription and lectotypification of *Cycas rumphii* (Cycadaceae). *Brittonia* 54(4): 305–309.

Linnaeus C (1747) *Flora Zeylanica.* (Holmiae [Stockholm]: L. Salvii)

Linnaeus C (1753) *Species Plantarum*, vol. 1. (1960 facsimile). (Engelmann: Weinheim)

Linnaeus C (1754) *Genera Plantarum*, 5th edition (1934 facsimile). (Shokobutu Bunken: Tokyo)

McNeill J, Barrie FR Burdet H-M, Demoulin V, Hawksworth DL, Marhold K, Nicholson DH, Prado J, Silva PC, Skog JE, Wiersema JH, Turland NJ (eds) (2006) *International Code of Botanical Nomenclature (Vienna), adopted by the Seventeenth International Botanical Congress, Vienna ,Austria, July 2005. Regnum Vegetabile 146.* (Gantner: Ruggell)

Miquel FAW (1839) Melanges botaniques. *Bulletin des Sciences Physiques et Naturelles en Neerlande* 2: 36, 44–46.

Miquel FAW (1842) *Monographia cycadearum.* (Rhenum: Utrecht)

Miquel FAW (1851) *Analecta Botanica Indica.* (Sulpke: Amsterdam)

Miquel FAW (1868) Nouveaux matériaux pour servir à la connaissance des Cycadées. Archives Néerlandaises des Sciences Exactes et Naturelles 3(5): 193–254, 403–427.

Paijmans K (1976) Vegetation. Pp. 23–105 in Paijmans K (ed.) *New Guinea Vegetation.* (Elsevier: Amsterdam)

Pant DD (1962) *Cycas and the Cycadales.* (Central Book Depot: Allahabad)

Pant DD (1973) *Cycas and the Cycadales,* 2nd edition. (Central Book Depot: Allahabad)

Pant DD, Singh R & Chauhan DK (1994) On *Cycas pectinata* Hamilton from north-east India. *Encephalartos* 38: 17–30.

Pilger R (1926) Cycadaceae. Pp. 44–82 in Engler A (ed.) *Die naturlichen pflanzenfamilien*, edition 2, 13. (Duncker & Humblot: Berlin)

Raizada MB & Sahni KC (1960) Living Indian gymnosperms part 1: Cycadales, Ginkgales and Coniferales. Indian Forestry Records: Botany. (n.s). Bot. 5. (1–4): 73–150.

Regel E (1863) *Cycas riuminiana* Porte. *Gartenflora* 12: 16–17.

Rendle AB (1900) Gymnosperms. Pp. 193 in Andrews CW (ed.) *A monograph of Christmas Island.* (Longmans: London)

Rheede HA (1682) *Hortus indicus malabaricus*, vol. 3. (van Someren, van Dyck & Boom: Amsterdam)

Ridley H (1925) Cycadaceae. *Flora of the Malay Peninsula* 5: 283–285.

Roxburgh W (1814) *Hortus Bengalensis.* (Mission Press: Serampore)

Roxburgh W (1832) *Flora Indica and descriptions of Indian plants.* (Thacker: Calcutta)

Schuster J (1932) Cycadaceae. Pp. 1–168 in Engler A (ed.) *Das Pflanzenreich* 99(4,1). (Engelmann: Leipzig)

Sealy JR (1975) William Roxburgh's collection of paintings of Indian plants. *Endeavor* 34: 84–89.

Singh R (2007) *Cycas annaikalensis*, a new species from the Western Ghats of India, with discussion on the specific limits of *C. circinalis* in Osborne R (ed.) *Proceedings of the Seventh International Conference on Cycad Biology. Memoirs of New York Botanical Garden Vol. 99* (in press).

Singh R & Radha P (2006) A new species of *Cycas* from the Malabar Coast, Western Ghats, India. *Brittonia* 58(2): 119–123.

Smitinand T (1971) The genus *Cycas* Linn. (Cycadaceae) in Thailand. *Natural History Bulletin of the Siam Society* 14 (1–2): 163–175.

Smitinand T (1972) Cycadaceae. Pp. 185–192 in Smitinand T & Larsen K *Flora of Thailand*, vol. 2(2). (Applied Scientific Corporation of Thailand: Bangkok)

Stapf O (1916) *Cycas Thouarsii. Kew Bulletin of Miscellaneous Information* 1–8.

Stevenson DW (1992) A formal classification of the extant cycads. *Brittonia* 44: 220–223.

Stone BC (1970) The Flora of Guam. *Micronesica* 6.

Suvatabandhu K (1961) The living gymnosperms of Thailand. *Journal of the National Research Council Thailand* 2: 59–62.

Tang WT, Yang SL & Vatcharakorn P (1997) *Cycads in Thailand*. (Nong Nooch Garden: Chonburi)

Thiselton-Dyer WT (1881) Cycads of Indian Peninsula. *Gardeners Chronicle*, Aug 27: 270.

Thiselton-Dyer WT (1883) On a new species of *Cycas* from southern India. *Transactions of the Linnaean Society London. Botany. series 2.* 2: 85–86, pl. 17.

Thiselton-Dyer WT (1888) Cycadaceae. Pp. 655–658 in Hooker WJ *Flora of British India*, vol. 5. (Reeve: London)

Thiselton-Dyer WT (1902) Cycadaceae in Forbes FB & Hemsley WB, An enumeration of the plants of China. *Journal of the Linnean Society, Botany* 26: 559–561.

Thiselton-Dyer WT (1905) *Cycas micholitzii. Gardeners Chronicle series 3.* 38(973): 142–144.

Thunberg CP (1784) *Flora Japonica*. 229. (Mülleriano: Lipsiae)

Trimen H (1898) *Flora of Ceylon*, vol. 4. (Dulau: London)

Walter KS & Gillett HJ (eds) (1998) 1997 IUCN Red List of Threatened Plants. Compiled by the World Conservation Monitoring Centre. (IUCN - The World Conservation Union: Gland)

Walters T & Yang SL (1994) The cycads of China – findings from the Montgomery Foundation / Fairchild Tropical Garden 1992 expedition. Pp. 6–11 in Tang W (ed.) The Cycads of China. *Journal of the Cycad Society*, vol. 1.

Wang DY (1996) Systematic classification and taxonomy. Pp. 9–142 in Wang F-X & Liang H-B (eds) *Cycads in China*. (Guangdong Science and Technology Press: Guangdong)

Warburg O (1900) Cycadaceae. Pp. 178–181 in Warburg O (ed.) *Monsunia*. (Engelmann: Leipzig)

White CT (1922) A contribution to our knowledge of the flora of Papua. *Proceedings of the Royal Society of Queensland* 34: 5–65.

Whitelock LM (2002) *The Cycads*. (Timber Press: Portland)

Wijnands DO (1986) Linnaeus's attitude towards cultivated plants. *Acta horticulturae* 182: 67–78.

Yuncker TG (1959) *Plants of Tonga. Bernice P. Bishop Museum Bulletin 220.* (Bernice P. Bishop Museum: Honolulu)

Zamora PM & Co L (1986) *Guide to Philippine flora and fauna 2: Descriptions of Gymnosperm species.* (Ministry of Natural Resources & University of the Philippines: Quezon City)

Zhou L, Yang SY & Zhou Z (1990) Investigation of the natural community of *Cycas panzihuaensis* L.Zhou & S.Y.Yang. *Memoirs of the New York Botanical Gardens* 57: 148–151.

Manuscript received 16 August 2006, accepted 15 May 2007

Corrigendum — Telopea 11 (3)

***Veronica* sect. *Labiatoides* Wettst. not '*V.* sect. *Derwentia*'**

Briggs BG & Ehrendorfer F (2006) New Australian species and typifications in *Veronica* sens. lat. (Plantaginaceae). *Telopea* 11 (3) 276–292.

Briggs BG & Ehrendorfer F (2006) Chromosome numbers of Australian and New Guinean species of *Veronica* (Plantaginaceae). *Telopea* 11 (3) 294–298.

In these papers we discussed the evolution of *Veronica* in Australia, using a proposed sectional name ('*V.* sect. *Derwentia*') for the clade of *Veronica* that includes most of the Australian members.This sectional name was not formally published. Since these papers went to press we have become aware that there is, however, an existing name applicable to this group, i.e. *Veronica* sect. *Labiatoides* Wettst. A type was not designated by Wettstein (1891, page 86) but lectotypification is being made in Garnock-Jones et al. (2007).

References

Garnock-Jones P, Albach D & Briggs B (2007) Botanical names in Southern Hemisphere *Veronica* (Plantaginaceae) sect. *Detzneria*, sect. *Hebe*, and sect. *Labiatoides*. *Taxon* 56 (in press).

Wettstein R (1891) Scrophulariaceae. In Engler HGA & Prantl KAE, *Die Natürlichen Pflanzenfamilien* 4 (3B) 39–107.

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